

**THE EFFECTS OF DIFFERENT VERBAL TEACHING STYLES
ON ATTAINMENT IN PHYSICS OF EDUCATIONAL OBJECTIVES
IN THE COGNITIVE AND AFFECTIVE DOMAINS.**

**a thesis submitted by
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DECLARATION

I hereby declare that this thesis was composed by me at the University of Edinburgh. Except where due acknowledgment is made it is entirely my own work, and has not been submitted by me for any other degree.

[REDACTED]

April, 1974.

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LIST OF CONTENTS

Chapter	Page
1. Classroom Behaviour.....	1
2. Science Teaching.....	26
3. Educational Objectives and their Evaluation..	46
4. Preliminary Investigation.....	76
5. Assessment of Verbal Teaching Styles.....	95
6. Evaluation of Cognitive Attainment.....	145
7. Evaluation of Attitude Development.....	189
8. Conclusions.....	227
References....	235
Appendix I.....	246
Interview schedule	
Appendix II.....	252
Transcripts of teacher interviews with teachers rated most open-ended and most expository.	
Appendix III.....	310
Instructions to experts concerning ranking of interview transcripts.	
Appendix IV.....	311
Attainment test I.	
Appendix V.....	312
Attainment test II.	
Appendix VI.....	313
SCE II: Question paper for the Scottish Certificate of Education in physics at the Ordinary Grade 1973 paper II.	
Appendix VII.....	314
Analysis of covariance of dependent variables using best 'weighted' composite of covariates - statistical procedure.	
Appendix VIII.....	323
Attitude questionnaire - pretest version.	
Appendix IX.....	324
Attitude questionnaire - final version.	

LIST OF TABLES

Table		Page
1.	Typical relative category frequencies for observed lesson	105
2.	I/D ratios for data obtained during preliminary investigation	115
3.	TQR's for data obtained during preliminary investigation	115
4.	Spearman rank correlation coefficients between ratios and occasions	116
5.	List of topic statements	119
6.	Ratio of indirect to direct teacher influence - I/D ratio index	124
7.	Mean I/D index for different teaching styles .	125
8.	Aggregate relative frequencies for each interaction category	126
9.	Observation data from comparable studies of physics teachers	129
10.	Rank order summation matrix for all experts ..	134
11.	Coefficient of concordance W for each topic ..	136
12.	Rank order matrix for all experts based on summation matrix - Table 10	137
13.	Rank order summation matrix for all experts for each style	138
14.	Ratings assigned to different teaching styles and sign differences	140
15.	Inter-style comparison using the sign test ...	141
16.	Comparison between teachers ranked for (i) I/D ratio and (ii) interview	144
17.	Content analysis grid for physics objective test	152
18.	Facility value and objective category for items in Attainment Test I	156

LIST OF TABLES (continued)

Table	Page
19. Facility value and objective category for items in Attainment Test II	157
20. Decisions of judges about educational objectives for items	159
21. Outline of research design	164
22. Attainment Test I - initial means - independent and dependent variables for different teaching styles	167
23. Attainment Test II - initial means - independent and dependent variables for different teaching styles	168
24. S.C.E. I & II - initial means - independent and dependent variables for different teaching styles	169
25. Kuder-Richardson-Formula 20 - reliability coefficients for objective tests	172
26. Adjusted analysis of marks in category A + B items in Attainment Test I after allowing for differences in students' IQ and social status rating (optimally weighted)	174
27. Attainment Test I - Attainment means after adjustment for IQ and social status difference	175
28. Attainment Test II - Attainment means after adjustment for IQ and social status difference	176
29. S.C.E. I - Attainment means after adjustment for IQ and social status difference	176
30. S.C.E. II - Attainment means after adjustment for IQ and social status difference	177
31. Analysis of differences among individual adjusted means within columns for Attainment Test I (categories A + B, and total) and SCE II	178
32. Correlation coefficients between students' total scores in attainment tests	180
33. Correlation coefficients between students' scores in items testing categories A + B in objective attainment tests	181

LIST OF TABLES (continued)

Table	Page
34. Correlation coefficients between students' scores in items testing categories C + D in objective attainment tests	182
35. Correlation coefficients between students' scores in attainment tests irrespective of teaching style	183
36. Mean score per item for objective tests	185
37. Pilot questionnaire statements and their related objectives	197
38. Intercorrelations between pre-test scores on different scales	199
39. Item analysis for all statements in attitude questionnaire	202
40. Split-half and Spearman-Brown reliability coefficients for each Likert scale, using pretest data	203
41. Finalised questionnaire statements and their related attitudes	204
42. Schematic outline of research design	205
43. Student scores on attitude questionnaire	207
44. Attitude shifts measured from scores in questionnaire	207
45. Means and mean differences of student scores in attitude questionnaire	208
46. Mean and variance of student scores in attitude questionnaire irrespective of teaching style ...	209
47. Overall mean differences of student scores in attitude questionnaire	209
48. Mean student IQ and social status rating for different teaching styles	210
49. Analysis of variance of student IQ scores	211
50. Analysis of variance of student social status ratings	211

LIST OF TABLES (continued)

Table	Page
51. First analysis	214
52. Final adjusted covariance analysis of z_2 using z_1 as covariate	215
53. Table of adjusted style means of z_2 with z_1 as covariate	216
54. 'F' for analysis of covariance of z_2 using z_1 as covariate	218
55. 'F' for analysis of covariance of z_3 using z_2 as covariate	218
56. 'F' for analysis of covariance of z_3 using z_1 as covariate	219
I Analysis of covariance of dependent variable z_1 with the independent variables x and y as covariates	318
II Table of adjusted means of z_1	320

SUMMARY

This thesis gives an account of a longitudinal study of the effects of different verbal teaching styles on the learning of physics by 14-16 year old students following an 'O' grade course for the Scottish Certificate of Education.

The verbal teaching styles of six experienced physics teachers are identified on a continuum ranging from open-ended to expository using the Flanders interaction analysis technique. According to the I/D ratio, two teachers are identified as extremely open-ended, two as extremely expository, the other two being intermediate between these extremes. The extent to which teachers classified as extreme merit this description is tested by comparing coded observation data for these teachers with that obtained for two criterion teachers described respectively as extreme exponents of the open-ended and expository styles of teaching physics in the country as a whole according to the subjective judgments of experts. The comparison indicates that the six teachers studied here represent the full spectrum of styles of teaching physics in Scotland. An interview with each teacher is tape recorded and the transcripts assessed by judges to find how a degree of authoritarianism on the part of the teacher is related to his verbal teaching style.

The effects are studied of contrasting verbal teaching styles on the attainment by students of

educational objectives in physics in the cognitive and affective domains. At various stages over a period of two years students taught physics only by these teachers are given tests of attainment of the cognitive objectives specified for the course. To evaluate student development in the affective domain an attitude questionnaire comprising Likert scales is administered on different occasions throughout the two year period.

Analyses of variance and covariance are used to equalise the 'between styles' differences in IQ and social status of students which are regarded as important independent variables affecting achievement outcomes. These statistical techniques are also used to adjust for the effects of 'between styles' differences in initial strength of attitudes as evidenced by initial scores in the attitude questionnaire.

The results suggest that in the cognitive domain the open-ended style of physics teaching may be more successful than the expository style in assisting students to achieve the more complex objectives, but that students taught in the expository mode may achieve more consistent results. The aspect of verbal teaching style investigated here does not appear to markedly influence development of student attitudes towards physics.

CHAPTER 1

CLASSROOM BEHAVIOUR

INTRODUCTION.

What makes for a good education? Is it the quality of the teaching, the characteristics of the students or the excellence of the school buildings and facilities? To the perceptive observer the learning situation is characterised by subtle interactions among different human beings engaged in a complex activity in the course of which they relate to one another and to their surroundings. The quality of the total educational process, however it is judged, inevitably depends on matching the activities of teachers and students with the conditions in which these activities occur. Despite the complexity of the teaching and learning milieu and the consequent difficulty of analysing it into its constituent parts, some attempt must be made to find how an activity which consumes massive human resources and a great deal of money, can be made to function most effectively.

There are many criteria by which the effectiveness of the educational process may be judged. Some of these are based on social or political values about which there may be no general agreement among educators. The criterion common to most agreed value judgments about what constitutes an effective educational strategy is that its implementation leads to certain levels of achievement by the students. However, substantial disagreement about what these levels are and how they

are best achieved is not uncommon. Are certain teaching strategies more successful in promoting desirable educational goals? If so, are there certain identifiable teacher behaviours or recognisable teacher characteristics associated with these strategies? Are these teaching strategies effective with all kinds of students when used by all kinds of teachers; or is a method which is best for one kind of teacher teaching a particular kind of student less successful in other circumstances? Is the learning environment an important factor? Does a specific teaching strategy require for its fulfilment a particular type of physical environment? Do students learn better in small groups than in large ones? Will they succeed in a new school building when they would have failed in an old one? How important are students' experiences outside school altogether in determining achievement levels?

Attempting to devise research strategies which might provide evidence on any one of these points is futile unless some way can be found of dealing with the many concomitant variables surrounding it. The multiplicity of variables influencing student outcomes and the impossibility of identifying some of them makes it impossible to control variables in educational research in the way that one might expect to do when carrying out research in the physical sciences, for example. Writing about research in physics education Elton (1972) says,

"In all good research experiments are designed on the basis of a framework of ideas and theories, and the scientist who denies the existence of such a framework has merely failed to make his presuppositions explicit and is the least likely ever to recognise their limitations or the point at which experiment proves them false. To the extent that frameworks in the social sciences are more subjective, less generally agreed and more likely to be challenged than in the physical sciences, a greater part of the intellectual effort of research in the social sciences goes into the framework itself rather than in what one does within the framework." He continues:-

"The second aspect which is common to all good research is the verification of theory by experiment and the willingness to alter a theory, if experiment does not support it. an experiment should be designed in such a way that any conclusions reached are unequivocal. Unfortunately, this is easier said than done in the social sciences where it is rarely possible to isolate a single variable without trivialising the problem and where the Heisenberg uncertainty principle works on the macroscopic scale of people. These are inescapable facts....."

Many attempts have been made during the past sixty years to isolate variables in the learning situation which affect student achievement. Much of that research has been a study of classroom behaviour. It has been concerned with

different aspects of the behaviour of students and of teachers and more recently with the way in which teachers and taught interact with each other. Some studies, however, have focused on other aspects of the learning environment. Most have been bedevilled by the difficulties described by Elton.

The investigation described here represents another attempt, particularly important at the present time because of recent curricular changes in science teaching, to identify specific teacher behaviours which affect learning outcomes.

In view of the large annual investment in the education of teachers it is clearly important to identify such variables if they exist and as far as possible to deploy the new knowledge thus obtained in more effective teacher education. For example, if research were to confirm that student learning is improved when the teacher increases the intellectual freedom of his students by asking open-ended questions then teachers in training should be encouraged to ask open-ended questions.

The problem.

One aspect of teacher behaviour that has been highlighted by the recent curricular changes referred to above and described elsewhere in this thesis (p. 39), is the verbal style adopted by the teacher in dealing with the class. The problem considered in the research reported here deals with the effects of the physics teacher's verbal style on the success of student learning

in physics and in shaping student attitudes to physics.

INDEPENDENT VARIABLES AFFECTING STUDENT ATTAINMENT

Before erecting the framework within which this problem can be tackled it is essential to consider the other independent variables in the learning situation which might influence the dependent variables to be investigated. Such independent variables may be classified in three main groups; (A) student characteristics, (B) teacher characteristics, and (C) other variables associated with the learning environment. Each of these is capable of further sub-division.

A. Student characteristics.

These may be grouped into three sub-categories:

(a) intellectual factors, (b) personality factors, and (c) sociological factors.

(a) The effect of intellectual factors on student attainment has been very thoroughly researched over a long period. Studies using either a single overall measure of intelligence or a battery of measures each determining a single aspect of performance are numerous. In most cases the research design requires achievement at some educational level to be correlated with the measure or measures of intelligence. Many such studies employ intellectual factors as predictors of later attainment. Some of the more important of these are discussed by Lavin (1965, pp.47-63). Since intelligence is generally recognised as being related to problem-solving

abilities and as these abilities are useful in academic achievement it is hardly surprising that most studies of the effects on student achievement of student intellectual factors related to intelligence yield positive results. More recent investigations in this area show a concern for the idea of intellectual 'style' rather than level of intellect as an important factor in student achievement. A study by Grophey and Field (1969), which exemplifies this trend, is discussed later (p. 82).

(b) It is generally accepted that intellectual factors account for less than half the variation in student achievement. Among the non-intellectual factors that have been considered in past investigations are those related to student personality, such as motivation, anxiety, study habits, neuroticism, conformance and independence. Many of these studies have at best indicated only a weak relationship between personality characteristics and educational attainment. The use of the personality inventories devised by Eysenck and Cattell has often resulted in conflicting results. Working with undergraduates Furneaux (1962) reports that 'neurotic introverts' are less likely to fail academically; while among school children Hallworth (1964) shows that 'stable extraverts' have superior school attainment. A study by Entwistle and Cunningham (1968) of about three thousand 13 year old students, finds that girls who are 'stable extraverts' and boys who are 'stable introverts' show the highest school attainment. It may

be that the comparative lack of success in finding important student personality factors related consistently to student achievement is a result of investigating these without taking account of the social and other factors surrounding them. An interesting study by Gardner(b) (1973) discussed in more detail in chapter 7 considers the interaction between individual pupil and teacher personality characteristics and how these affect student achievement of educational goals. It may be that the interaction of personality with social factors has an important bearing on academic attainment.

(c) The third group of student characteristics that are of interest in considering student achievement consists of sociological factors such as socioeconomic status, and social relationships both within the learning environment and beyond it. By far the most widely researched of these is the students' social and economic status. Many studies of this kind report that social status varies directly as academic performance. The U.C.C.A. statistical supplement to the report for 1967-8 shows that of candidates accepted for admission to university through the UCCA scheme in October 1968, 44 per cent belonged to the upper parental occupation groups (administrators and managers; professional and technical workers) although only 14 per cent of economically-active males aged 45 to 59 in Great Britain belonged to that group. On the other hand, although 64 per cent of the male population is shown as belonging

to the occupation group designated as 'manual and agricultural' this group accounted for only 28 per cent of the student intake in 1968. Lavin (1965, p.149) after reviewing studies concerned with the effects of social factors on student achievement concludes: (i) that socio-economic status and achievement are related at all academic levels; (ii) that measures of student social acceptability are related to attainment as are signs of warm family relationships; and (iii) that the student's academic attainment is improved where his values and attitudes are shared by the teacher. This last factor reinforces the well documented fact that students whose parents belong to the lower social and occupational prestige groups are less likely to be academically successful, Robbins Report (1963).

B. Teacher characteristics.

It is perhaps appropriate to classify teacher characteristics into three groups: (a) characteristics associated with the teacher's knowledge, professional qualifications and experience, (b) teacher personality factors either as perceived by the teacher himself, by his students or by an independent observer, and (c) overt teacher behaviours associated with teacher performance in the classroom.

Sharp (1966) reporting on a study of characteristics of high school biology teachers states that teachers' subject knowledge, years of teaching experience, and academic qualifications do not appear to be related

to student attainment. Rothman, Welch and Walberg (1969) also report that in their study of 35 male teachers of physics, there is no significant relation between teacher experience, preparation for teaching or subject knowledge and student cognitive or affective attainment. Yager (1966) regards teacher attitudes towards biology as an important factor in influencing student outcomes although his report does not indicate which aspects of student cognitive achievement are affected. The attendance of science teachers at a summer in-service course is reported by Thelen and Litski (1972) to have had an impact on subsequent student attainment as measured by tests of knowledge. Their study does not attempt to control some concomitant variables which the authors concede restrict the generality of their findings.

Among teacher personality factors regarded as important by Gage (1972) is 'warmth'. Quoting Heider, Gage (p.52) argues that "Warm teachers are perceived by students as liking them, and the students tend to reciprocate the affection." Gardner's study referred to above finds some physics teachers rated highly by their students in warmth. These teachers are regarded as being intellectually stimulating and are reported as being successful in teaching intellectually intense students and in promoting enjoyment of physics in most students. The study by Rothman, Welch and Walberg mentioned above indicates that the value systems and personality of the teacher do influence both cognitive and attitude attainment in his students. The most

important trait identified¹⁰ by these workers is the heterosexuality of the teacher. In a later study by Rothman (1969) concerning 51 physics teachers, the effects on student development of teacher personality factors and aspects of teacher preparation are investigated. Rothman, suggesting that the previous study by Rothman, Welch and Walberg might be faulted for bias in the sample of teachers used, reports that while 70 per cent of the variance in student cognitive development may be attributed to teacher personality only about 12 per cent seems to be related to teacher factors connected with qualifications, experience and so on. He reports interestingly that although students seem to learn best from well qualified teachers with a good understanding of physics such students seem quickly to lose interest in physics. The same writer is unable to identify significant personality traits but states that the teacher's need for heterosexuality although not significant in that study is more strongly related to student learning than other factors, thus repeating the finding of the earlier research. He argues that this effect may be explained in terms of male student identification with teachers of this kind.

In a review of research carried out between 1960 and 1966, into teacher effectiveness, Flanders and Simon (1970) report that a study by Heil and Washburne (1962) indicates an interaction between different teacher types and different student types. The three teacher types investigated by these workers are labelled: impulsive,

controlled and fearful. The student types identified are called conformers, opposers, waverers and strivers. As with Rothman, Flanders and Simon stress the need for research which involves the matching of student types with teacher types.

Commenting in the same review on process-product studies into the effects on learning outcomes Flanders and Simon conclude that 65-75 per cent of all talk is teacher talk and that most student talk is in direct response to teacher questions. They conclude that a more responsive pattern of teacher verbal behaviour would lead to higher student attainment. In another report reviewing research into teacher behaviour variables Rosenshine and Furst (1971) contend that among the variables which seem to be related to student achievement are: (i) clarity of teacher's presentation, (ii) teacher's use of a variety of teaching strategies, (iii) teacher's enthusiasm, (iv) businesslike behaviour by the teacher, and (v) student opportunity to learn the test material. It is suggested that there is so far little evidence to suggest that teacher approval or praise or certain modes of verbal teaching style including these investigated in the research to be described in this thesis, are important in affecting student achievement. The authors end their review with a plea for more well-designed research into the effects of particular kinds of teacher behaviour on student learning outcomes.

Rosenshine (1971, p.61) having reviewed research

related to the use of criticism concludes that "...there is no evidence to support a claim that a teacher should avoid telling a student that he is wrong, or should avoid giving academic directions. However, teachers who use a great deal of criticism appear consistently to have classes who achieve less in most subject areas." He again states the inconclusive nature of the relationships between student achievement and such things as teacher praise, the use of students' ideas by the teacher, and ratio of teacher approval to teacher disapproval statements. Dealing with what he calls 'teacher cognitive behaviours', Rosenshine surveys studies of achievement-oriented behaviour by the teacher and concludes that teachers rated as task oriented or businesslike are successful in promoting student attainment. Writing about research into clarity of presentation by the teacher this author quotes a study by Wright and Nuthall (1970) which indicates that teacher statements containing only one question are significantly related to student achievement while statements containing two or more questions along with teacher information are negatively related to achievement. It seems reasonable to comment on this point that successful teachers probably ask questions clearly and only have to ask a single question as a result. Rosenshine (p.107) claims that "...results on clarity are most consistent and significant, particularly in contrast to the results of other variables." On perceived student difficulty of the lesson the results

are inconclusive. Another factor which that review indicates might be significant is the degree of structuring by the teacher before and after a question is asked. Rosenshine, citing the work of Wright and Nuthall again, regards this as an important area for future research. Among the other cognitive teacher behaviours referred to are pacing, diversity of purpose by the teacher and teacher's cognitive response to student statements. Because the evidence on these matters is mixed it is doubtful if firm conclusions can be drawn. A review of research into the flexibility of teachers' cognitive behaviour and the variety of the classroom activities indicates that such factors are significantly related to student achievement. Rosenshine notes that several studies relate student achievement to the opportunity afforded earlier to learn material of a similar type and involving similar cognitive processes. He goes on to say that such studies, including the largest, the IEA study of mathematics achievement (Husén, 1967), show consistently high bivariate correlations. It would indeed be surprising to find otherwise since the 'practice effect' is well established. It could indeed be argued that some cognitive processes may become different processes when they are no longer unfamiliar.

Ratings on teacher enthusiasm are usually related to some aspect of student attainment. Unfortunately, as Rosenshine suggests it is difficult to agree about

the behavioural correlates of enthusiasm. The studies reviewed by Rosenshine (1970, pp.148-152) generally interpret teacher enthusiasm in different ways, making any firm conclusions hard to draw.

C. Characteristics of the learning environment.

Many studies of learning effectiveness have indicated that much of the variation in student attainment cannot be attributed to specific student or teacher characteristics. In this situation it is perhaps inevitable that researchers will focus their attention on factors associated with the physical environment of the learning milieu and with the socio-emotional climate in the classroom.

Among factors of this kind that have been studied are teaching duration. The amount of teaching time used in instruction and its relation to student achievement has been studied for many years. Early research suggested that time spent bears no relation to student attainment. A much more recent study is that of Welch and Bridgham (1968) who conducted an investigation of 41 teachers and about 2000 students over a period of one year. They report that in the Harvard Project Physics course neither achievement gain nor student ability as measured using a test of mental ability is significantly related to teaching duration. Two conclusions drawn from these findings are; (i) that it is probably unfruitful to omit part of a course in order to spend additional time on the remainder,

and (ii) that time spent in teaching at a particular stage may be related to the habits or interests of the teachers rather than because of a perceived student difficulty. Both the IEA mathematics study indicated above and the more recent IEA science evaluation study by Comber and Keeves (1973) show the variable 'time devoted to all homework' yielding higher correlations with student achievement in mathematics or science than either of the variables; 'time devoted to mathematics homework', or 'time devoted to science homework'. It might be unwise to regard 'time spent in homework' as an important learning variable.

A recent investigation of the impact of environmental factors on student achievement is that of Walberg (1969). One of the fourteen scales used deals with such aspects of the learning milieu as the number of books and amount of science equipment available. The study is concerned with eleventh and twelfth grade students following a Harvard Project Physics course. Walberg reports a significant correlation between scores on the 'environment' scale and student achievement scores, indicating that the level of provision of such learning resources as books and equipment may be vital factors in influencing student learning.

Perhaps one of the most important studies of the social climate of the classroom and its effect on student learning is that of Anderson and Walberg (1968). In their study, designed to relate class gains in understanding,

achievement and attitude of twelfth grade physics students to group perceptions of classroom climate, these workers use a classroom climate questionnaire comprising statements to which students are asked to respond on a five point agreement-disagreement rating. The scales cover such factors as Disorganisation, Social Heterogeneity, Formality, Strict Control, and Friction among class members. Tests of science understanding, physics achievement and a semantic differentials scale of affect are used as criteria for student achievement. An IQ test is also used in an attempt to estimate the amount of criterion variance due to IQ alone. Multiple correlations for the classroom climate variables with each of the criterion variables show that only in the case of the physics achievement test is the correlation significant. Further investigation of the separate classroom climate factors shows that high levels of Disorganisation, Formality and Social Heterogeneity are not conducive to achievement. When the three criteria of student achievement are considered collectively the results suggest that high scores on some climate factors - Friction, Personal Intimacy and Strict Control - and low scores on others - Disorganisation, Stratification, Subservience and Formality - indicate conditions favourable to student learning. It must be said that the opposite loadings of Strict Control and Formality cast doubts about these conclusions. The authors admit a correlation of 0.56 between these factors. The finding that gains in physics achievement are negatively correlated with gains in

science understanding is difficult to comprehend. It is not easy to agree with the authors' conclusion that the kind of classroom climate which promotes physics achievement discourages scientific understanding and interest in physics. The promised replication of this investigation should show whether 'classroom climate as perceived by the students' is an important factor in student learning. Perhaps the different student and teacher characteristics which shape the classroom climate are the more important elements.

In this survey of independent variables of the learning situation which could be regarded as important in determining learning outcomes, the weight of research evidence suggests that among student characteristics which ought to be controlled are general intelligence and social status; and that among teacher characteristics the teacher's subject knowledge and professional qualifications warrant consideration as factors likely to promote student learning. The bulk of research supports the view that teacher behaviour does influence student learning although investigation has not so far led to the identification of the crucial teaching acts.

Much of the research so far carried out into teacher behaviour has been concerned with various aspects of verbal behaviour in the classroom. The study described in this thesis deals specifically with the teacher's verbal behaviour. Regarding possible variables connected with the learning situation, of these looked

at only the quality of the physical environment seems to matter. In the experimental work about to be described steps are taken to control the most important student, teacher, and learning environment variables.

ANALYSIS OF CLASSROOM BEHAVIOUR

One of the earliest studies of classroom behaviour is that of Stevens (1912) who found by analysing type-scripts of lessons that teachers' talk amounted to two thirds of all organised talk in the classroom. Morrison (1927, p.103) writes that "The major elements in the learning situation are motivation and attention," and goes on to describe motivation as "... a desire to learn." He sees the key to effective teaching and learning as the ability of the teacher to hold the attention of the whole class during a period of exposition; this teacher skill is called group control. The capacity to maintain group attention is called sustained attention. Morrison refers to the need to set up teaching objectives which he defines as mastery of parts of the course. He concludes that "...while poor control technique always means poor teaching, good control technique does not necessarily mean good teaching." The methods of measuring group control and sustained attention using a stop watch which Morrison recommends must be among the earliest forms of observation of behaviour in the classroom. More recent attempts to understand the classroom situation are also based on the collection of classroom data by an observer.

A different approach to the problem of interpretation of the learning situation is that described by Anderson (1939) who studied the adult-child relationship in terms of 'dominative' and 'integrative' behaviour. Domination is described as the "...behaviour of a person who is inflexible, rigid,...who disregards the desires or judgments of others...", while integrative behaviour is described as "...noncoercive; it is the expression of one who attempts to understand others...It is consistent with the scientific approach, the open mind." Anderson shows the effect of dominative-integrative behaviour on the number of teacher-student contacts per hour, and demonstrates its influence on student behaviour and on the capacity of the students to learn. Since his study involved the observation of children of kindergarten age it might be unwise to extrapolate the findings to older students. As Flanders (1965) points out, this dimension of teacher behaviour laid the foundation for the recent development of interaction analysis techniques, especially those which concentrate on 'direct' and 'indirect' teacher behaviour (p.102 of this thesis).

A famous study of patterns of aggressive behaviour and how these are influenced by the social climate is that carried out by Lewin, Lippitt and White (1939). Although in this case the 10 year old children were observed away from a classroom environment the study is of interest since it demonstrates how the behaviour of the leader (teacher) affects that of the group being

led (students).

A further stage in the development of observational techniques for classroom use is that reported by Withall (1949) who devised a system of classifying a teacher's verbal statements into seven categories; three learner-centred, three teacher-centred, and one neutral. Withall shows the technique to have cross-observer reliability and to be valid when tested against teacher behaviour categories previously devised by Anderson and Brewer (1945). He uses this technique to discover patterns of teacher verbal behaviour and to assess the social emotional climate in the classroom. Withall's procedure cannot properly be regarded as an interaction analysis technique since it does not take account of student verbal behaviour. It is nevertheless the forerunner of such analytical techniques as that used in the present investigation. Withall did not attempt to measure the effect of teacher behaviour patterns on student learning.

In 1951 Bales and Strodtbeck used a twelve category system in analysing problem-solving techniques as developed in group discussion.

By about 1958 users of classroom observation techniques were fully aware of the extent to which student behaviour and student learning is affected by teacher behaviour. A study by Anderson (1960) suggests that 'dependent-prone' students have

expectations of teacher behaviour which are different from those of 'independent-prone' students.

The realisation that teacher behaviour may affect student behaviour and vice versa caused researchers to develop observation systems for use in the classroom which record student statements as well as those of teachers. One of the best known of these interaction techniques is the system developed by Flanders (1960) and described in detail in this thesis, (chapter 5, pp. 99 - 109). This system measures what is called 'direct' and 'indirect' teacher influence where these terms correspond closely to the earlier 'dominative' and 'integrative' ideas of Anderson.

Since 1964 a large number of observational systems of interaction analysis have been developed. Some of these involve analysis of the verbal components of activity, others the non-verbal behaviours of teachers and students. Each of these systems employs 'episodes' during which observations are made and the length of an 'episode' varies from a few seconds to a period of several minutes. In some cases continuous recording is essential, in others not. Simon and Boyer (1970) describe 67 systems suitable for use in the classroom. These include those which focus on interaction between a single student and the teacher, and those which concentrate on interaction between the teacher and the whole class. Some of these systems are intended for use in a particular subject area. Others are regarded as

being more widely applicable.

The use of these systems permits patterns of interaction to be identified and allows different teaching behaviours to be related to student learning. Among recent studies of this kind is that of Allen (1969) who, investigating the effects of the teacher's verbal behaviour on number development in first-grade students, reports that the frequency of teacher questions and of teacher-student interactions, appears to be related to their achievement in mathematics.

A RESEARCH STRATEGY

The complex nature of classroom behaviour has been amply demonstrated. It is clear that designing a satisfactory framework within which to analyse certain aspects of the learning situation is a very difficult task. The multiplicity of independent variables which may have to be controlled makes it difficult to use the traditional process-product study. Ideally within this paradigm students are subjected to certain 'treatments' and their scores in some post-test of achievement compared either with one another or with those of a 'control' group who have not received the treatment. Such a research strategy results in dubious findings unless it can be shown that the groups being compared are similar as regards all other variables which might conceivably affect achievement. There are two methods of ensuring that such conditions exist. One is to

work with very large groups and allow chance to take care of the extraneous independent variables. However, the use of very large groups is usually impracticable on grounds of cost as well as of administrative difficulty. Its use in the study being described here would have entailed the involvement of a large number of schools, teachers and students as well as additional researchers thereby greatly increasing the cost.

The other method is to control these variables. But here the problem arises that in the analysis of classroom behaviour it is not always possible to identify still less to control all such variables. What is perhaps feasible for the educational researcher is to seek to identify the most important of the extraneous variables surrounding the particular problem of interest and to formulate a strategy to control these.

It is here that the anthropological research paradigm proposed by Parlett and Hamilton (1972) seems appropriate. Describing the organisation and method of this strategy the authors (p.16) say that "... the researcher is concerned to familiarise himself thoroughly with the day-to-day reality of the setting or settings he is studying. ...he makes no attempt to manipulate, control or eliminate situational variables but takes as given the complex scene he encounters. His chief task is to unravel it; isolate its significant features; delineate cycles of cause and effect; and comprehend relationships between beliefs and practices,

and between organisational patterns and the response of individuals. ...there is a definite emphasis both on observation at the classroom level and on interviewing participating instructors and students."

The research strategy advocated by these writers could be employed during the initial stages of an investigation such as that described here in order to better understand the cultural, social, institutional and psychological variables which comprise the learning milieu. Where the process-product study is preceded by an exploratory investigation of this kind the researcher should be in a better position in planning his research design to formulate the right hypotheses and identify the important variables.

This anthropological research paradigm is employed albeit in an imperfect fashion in the investigation described in this thesis. In this instance the teachers whose verbal style is the subject of the study are interviewed towards the end of the investigation and not at the beginning. It is claimed that their purpose in this case is to provide post-hoc evidence of the veracity of some of the earlier postulates.

The sole use of what Parlett and Hamilton call 'illuminative' research might be faulted on the grounds that the admittedly highly subjective judgments of the researcher may adversely affect the acceptability and generality of the findings since these would rest entirely on the investigator's perspicacity and on his

integrity, unsupported by experimental data.

It would appear that both research strategies could be advantageously employed in studies of classroom behaviour. The anthropological method could be used to explore the teacher-student interactions, the habits of thought and actions of the participants and the institutional factors in the learning milieu. This exploratory study would then allow the investigator to focus on the crucial issues. He is then better able to devise a research procedure capable of yielding data likely to lead to findings not invalidated by initial failure to identify all facets of the problem.

CHAPTER 2

SCIENCE TEACHING

INTRODUCTION

The earliest systems of mass education were based firmly on the ideas of 'instruction'. In Plato's Republic the subordinate managerial class were instructed in a body of doctrine conveyed as dogma open to no doubt or uncertainty; and this was the spirit in which educational strategies were conceived during the nineteenth century. During the latter part of that century science was taught as the acquisition of a specific body of knowledge comprising a series of final unchallengeable truths about the universe. The sudden explosion of new discoveries, especially in physics, during the first quarter of the twentieth century, although it shattered the tidy framework erected by nineteenth century scientists, made little or no impact on the teaching of science in schools which continued unaltered. Schwab (1962) suggests that by this time, when scientific knowledge and theories had begun to change rapidly, textbooks for use in schools were no longer being written by professional scientists but by school teachers who were not themselves practising scientists. In consequence, the contents of textbooks responded to changes in the scientific position only very slowly and thus 'real' science and the science taught in schools drifted apart. This proposition would explain the static condition of the school physics

syllabus in this country from 1890 to 1960; a matter referred to later in this thesis (p. 76). Perhaps the concern of the universities with mathematics as a preparation for the study of classical physics also contributed to this situation. Among other factors preventing new ideas from reaching the school curriculum was doubt about their basic truth - scientists kept hoping that they would be superceded by an all embracing 'true' theory. It is sometimes said that English scientists at that time were obsessed with 'models', particularly atomic models, and were reluctant to believe in an idea which could not be represented by a 'model'.

DISCOVERY LEARNING IN SCIENCE

Schwab points out that the gap which existed during that period between the current state of scientific knowledge and the body of scientific knowledge being taught in schools was accompanied by an equally wide gap between the experimental procedures of professional science and the reflection of these in the then current methodology of school science. He goes on to point out that while by its very nature scientific investigation suggests doubt about the finality of research findings in science, the experimental practices in school science laboratories had become exercises in the experimental verification of previously established principles presented as inalterable truths. In claiming that science was presented to

students in a way that stressed the importance of problem solving and the mastery of specified laboratory techniques, Schwab claims that the essential element of enquiry and discovery which characterises the work of real scientists was ignored; and that science was offered in a way which appealed only to the docile learner. Taught in this way science is seen as a process of theory leading to facts whereas in reality scientific theories lead not to facts but to other more complex or more general theories which themselves stimulate further experimental investigation.

Perhaps a major deficiency in the traditional style of science teaching is apparent when it is realised that scientific knowledge acquired at school rapidly becomes obsolete as it is overtaken by current developments in science. It therefore seems reasonable to adopt a teaching strategy which will lead the student to recognise that the criterion of scientific success is not the possession of many items of scientific information but the ability to display competence in methods of scientific enquiry.

In accordance with this aim the element of discovery must always be present in the science classroom. Work performed in the laboratory should be designed to allow the student to discover for himself by following the processes of scientific enquiry, rather than as a means of verifying what has already been established. In the former instance it is argued that the discovery strategy requires the student to seek to put alternative

interpretations on experimental data whereas under the expository procedure the student's aim is to seek the 'correct'-according to theory-answer. It is contended that the discovery method leads to discussion between teacher and students since different interpretations of the data will suggest not a 'right' but simply a more probable answer.

On the other hand, Keislar and Shulman (1966, p.189) pose the question of whether the students of a discipline in studying the subject matter ought to follow the activities of the practitioners of that discipline. These authors also point out that scientists do not spend all their time discovering and that in fact a large part of the professional time of the scientists is spent acting as the recipient of an expository learning process; for example by reading professional journals, listening to lectures and so on. There is much to be said for this point of view. In any event it is difficult to see how successful scientific discoveries are to be made unless scientists have already become familiar with the current state of knowledge. This knowledge is in the main acquired either as part of the scientist's formal education or by reading reports of research carried out by other scientists working in the same field. It does not seem to be either feasible or necessary for all science education to involve the student in a discovery situation. A further drawback of discovery learning in science is that while the doubts and uncertainties identified with

scientific discoveries may be accepted as part of the game by the mature experienced and recognised scientific practitioner they may create a sense of insecurity among young students especially since it is unlikely that such students will be required to 'discover' the prescribed body of learning in their other subjects. There is surely a case for teaching science using a mixture of the discovery and expository strategies so that students experience all the activities of science and not only these which typify the scientific revolutions - see p. 76 - but also the activities which precede and succeed these 'breakthroughs'. The need for moderation in this matter is all the more important since there is no clear research evidence to indicate that the discovery method is superior when achievement outcomes are considered.

An important study of the efficacy of the discovery mode of teaching is that of Ray (1961) who in a carefully regulated investigation compares the method of directed discovery teaching of micrometer principles and skills with the method of direct instruction working with ninth grade boys in junior high schools. Ray describes how three treatment groups of comparable IQ are tested in their ability to use a micrometer caliper. One group is taught in the traditional 'tell and do' method, a second group by a method of directed discovery while a third control group receives no teaching. No significant difference is reported on initial learning

between the two taught groups when tested immediately after the period of learning. All students are tested again one week and six weeks after learning. Analysis of the test results shows that although there is again no significant difference between the discovery and instructed groups after one week, the group taught in the discovery mode achieve significantly higher scores in the later test. Tests of transfer of learning are also given to the students after one and six weeks respectively. These show the discovery method to be superior on both occasions. Each treatment group is subdivided into three IQ levels: when the interaction of teaching method with intellectual level is examined no significant effect is discovered leading Ray to conclude that the discovery method although superior as regards retention and transfer of learning is not superior as a process in establishing initial learning. He also concludes that these results are not affected by student intellectual level.

Another noteworthy investigation of this problem is that of Babikian (1971) who compares three methods of teaching scientific concepts: an expository method involving no laboratory work; a laboratory method in which the students proceed to verify experimentally the concepts previously presented by the teacher; and a discovery method in which the students have to discover the concept for themselves by following a prescribed experimental procedure. This third method is similar to

that followed in most modern science syllabuses, such as those discussed (p. 39). The three student groups in Babikian's experiment are stated not to differ significantly from one another in IQ and other factors which might affect achievement outcomes. After stating his findings based on criterion tests of overall achievement, verbalisation of concepts, recognition of concepts, and the application of concepts to numerical problems, the author concludes that the expository and laboratory methods are significantly more effective than the discovery method in respect of all these measures. Babikian points out, however, that the students may have been unfamiliar with the discovery strategy.

A characteristic common to both these studies is that all treatments were administered by the same teacher - the investigator in each case - and it is conceivable that the outcomes may reflect teacher preference for a particular method; a teacher whose bent is essentially expository may teach badly when employing a discovery mode. The research being described here, by allowing the teachers to teach according to their natural preference excludes this bias but replaces it with another aspect of teacher variability. An effective expository teacher may be compared with an incompetent discovery one or vice versa. A second similarity between Ray's study and that of Babikian is that they concern eighth or ninth grade students of ages 12-13 years; such students should be responsive to the discovery style. It is sometimes argued that older

students cannot 'discover' what they have already learned in another way and that the natural curiosity of the younger student becomes suppressed in adolescence.

A study by Kersh (1962) involves teaching special rules of addition using the methods of guided discovery, directed learning and rote learning with similar groups. The criterion measures used in this study are (a) recall, and (b) transfer, both tested at periods of three days, two weeks and six weeks after learning. He reports rote learning to be superior to the other methods in all respects. Kersh does not state whether the treatment groups are pretested for comparability and it may be that the learning task selected for this investigation is loaded against a discovery strategy.

In an essay on the relation of discovery learning to science teaching, Bibergall (1966) quotes the advantages claimed by Bruner (1961) for discovery learning. It is claimed that; (a) it increases the learner's ability to learn related material, (b) it fosters interest in the activity itself rather than as a reward for learning, (c) it develops in the learner the ability to approach problems in a way likely to lead to a solution, and (d) it tends to aid retrieval and reconstruction of learned material. Listing the factors which might be used in assessing the success of discovery learning Bibergall concludes that although not all Bruner's claims can be supported, there are situations in science teaching where its use can be recommended.

Fisher (1969) comments on discovery learning in science and agrees tentatively with other researchers that discovery learning in science may lead to a stronger student motivation.

The investigation being described here deals with one aspect of the discovery method, an open-ended style of verbal interaction between teacher and students. X

CURRICULUM DEVELOPMENT IN SCIENCE

Schwab (1962), argued that there are many factors which influence decisions about curriculum development and that these may be grouped in four categories. These are:

1. social factors; reflecting the needs of society in general
2. learner factors; concerned with the individual needs of the students
3. teacher factors; related to the requirements and limitations of teachers
4. subject matter factors; caused by the nature of the subject itself.

It follows that curriculum development is subject to the pressures and constraints of these factors. Curriculum development in science over the past decade or more has undoubtedly been influenced by such determinants as these described above. Reference is made in chapter 4 (p. 76) to some of the changes embodied in the new physics curricula. It is clear for example that an updating of physics content is necessitated by the requirement for all educated men and

women to have an awareness of the environmental impact of physics, including, for example, the industrial implications of nuclear physics. Consequently a school physics curriculum which stops historically at 1890 is not reflecting social needs. It may be equally true that school students require to be acquainted with nuclear physics to facilitate their understanding of school chemistry. There may be several factors from different categories pointing to the need for curriculum development in a certain direction at a given time.

During the decade starting in 1960 physics curricula in schools underwent drastic changes in many parts of the world. Four of the major curriculum projects are described briefly below.

A. Physical Science Study Committee. (PSSC)

It was revealed in 1955 that only 4 per cent of American high school students studied physics. To rectify this state of affairs a radically different course was devised. This was designed to deal with the large ideas of physics. Finlay (1960) discusses the virtues and disadvantages of such an approach and goes on to say that "The structure of science is one of explanation. The explanatory systems of physics and how they are made have much more forward thrust as educational tools than the individual application and the discrete unconnected explanation." The same writer points out that topics which do not fit into this general framework are excluded from PSSC.

The course is designed as a one or two year course for American high schools where it is studied by students ages 16-17 years, many of whom have a relatively poor background in mathematics. Friskopp (1972), Finlay and others writing about the course emphasise that a principal aim is to develop students' abilities to "...learn how physicists work and how physics knowledge is built up", as Friskopp (p.309) expresses it. It is central to this aim that students learn to ask questions, plan experiments, collect and analyse data and draw sensible conclusions. To allow students to acquire new scientific knowledge and solve new problems the PSSC course is designed to give students real insight into the topics covered. Finlay explains that experimental work is intended to contribute to understanding of physical principles and the role of experimentation in science. The course is discovery oriented, the student being expected to deal with open-ended problems both in the laboratory and in the classroom.

The PSSC course was a forerunner of many others. Adapted for use in Scandinavia, Australia, New Zealand and elsewhere; it also forms the basis from which are developed the Scottish and Nuffield courses in the United Kingdom.

B. Scottish physics syllabus.

Established in 1962, the Scottish syllabus derives its fundamentals from PSSC. The Scottish course, however, is designed as a six year course, concyclic in nature,

for students between 12 and 18 years. A few themes such as energy, the small scale nature of matter, and the use of models in physics form the essential core of the course which consists of three cycles each of two years duration.

Like the other new physics syllabuses it incorporates many of the modern concepts in physics. It also stresses the importance of open-ended experimentation and the use of a strategy of directed discovery. Students are encouraged to devise their own detailed experimental procedure and to interpret their data with only minimal guidance from the teacher. Textbooks used are designed to encourage the student to induce the general physics principle from experience of a series of specific instances of it which he may have discovered in the laboratory. Examinations are constructed to test the student's ability to tackle open-ended problems for which there is no tidy prescribed solution, as well as to test his knowledge of some important principles in physics. Writing about the Scottish physics course Ritchie (1972) states that the second cycle "...emphasises the physics important for the future of the educated layman... and is designed to assist teachers to encourage (students) in developing their own attitudes of inquiry and a sympathetic understanding of their environment." The research being described here is concerned with the verbal style of Scottish physics teachers and the achievements of their students during the second cycle of this course.

C. Nuffield Physics Project.

The Nuffield 'O' level course is designed as a five year course for students aged 11-16 years who are in the top 25 per cent of the ability range. It has been described as a laboratory based course with the emphasis on student learning by inquiry and thus has much in common with other modern science syllabuses. The Nuffield 'A' level course, more recently developed, is a two year course for students aged 16-18 years, mainly in the sixth form of British secondary schools. Many of the students who follow the 'A' level physics course proceed to higher education courses usually requiring a further study of physics. Lewis (1972, p.354) estimates that about half of the students who take the course are in this category. The same author enumerates the course objectives as (a) preparing students for later studies; (b) assisting students to learn to take..."constructive, relevant steps towards the solution of problems for which they have not been given complete explicit rules of solution"; (c) aiming to improve students' abilities to "...discuss and reflect cogently upon the process of enquiry in physics"; (d) encouraging the student to learn to enquire; (e) increasing student awareness of the practical and social implications of physics; and (f) increasing the students' interest in and enjoyment of physics.

D. Harvard Project Physics.

Launched in 1964, this course has much in common

with the PSSC course which preceded it. It is organised around six basic units which are intended to comprise a course lasting from six to eight months. As in the case of PSSC the physics topics dealt with in the basic course are those which are regarded as being of the essence of physics, all embracing and enduring. Harvard physics emphasises the humanistic and technological links between physics and society. A feature of the course is the widespread use made of the devices of educational technology. This is in keeping with the course directors' aim of making the course as flexible as possible to meet the needs of different students. Many supplementary units have also been developed to assist this objective. The organisers claim that, again to quote Lewis (1972, p.336), the course assists ".... the preservation and exploitation of individual differences, both in teachers and in students, as a way to motivate the study of subject matter."

CLASSROOM EFFECTS OF NEW PHYSICS SYLLABUSES

It is clear from the foregoing account of recent syllabus changes that the new courses share much in common. They are similar in that they

1. are built around the basic overarching ideas in physics
2. have the aim of helping the student to see how physics works in explaining a coherent picture of the universe.

3. are designed to let the student see the relevance of physics in modern society from the standpoint of the non-scientist
4. present experimental work in an open-ended way allowing the student to plan his own procedures to some extent
5. expect the student to learn how to structure and analyse the data he has obtained and to draw conclusions from these data
6. employ multi-media learning aids
7. encourage directed discovery by the students.

These changes in teaching strategy suggest a fundamental change in the role of the physics teacher who must develop different skills and employ different teaching techniques from those used by his predecessors. A study carried out by Spore (1962) had the aim of identifying the professional competences of the science teacher in the secondary school. A list of sixty operational skills was compiled and submitted to four groups of judges who were (a) teacher educators in the fields of professional subjects, (b) teacher educators in science methodology, (c) practicing science teachers, and (d) administrators of science teachers.

Spore reports that among the thirty competences ranked highest by the combined judgments of the four groups are the ability to:

- (i) "be alert to the latest scientific developments, continuously revising lesson plans and materials to keep classroom experiences up-to-date

- (ii) guide students to sources of data and experimentation useful in the solution of their problems
- (iii) guide students to discover and structure problems so that they may be analysed by logical means
- (iv) develop in students a critical understanding of differences in conceptions of truth and methods of formal inquiry in science."

It is interesting to note that among skills not rated highly by the judges is the ability to

"evaluate...how the student reacts...in a problem situation requiring the application of generalisations drawn from classroom and other learning experiences."

A somewhat similar study by Farmer (1964) of the image of the science teacher also involves the rating of certain competences by teachers, administrators, science advisers, and science lecturers in colleges of education. The abilities rated highest by these groups in order of importance are; (a) effective use of laboratory work, (b) skill in handling students' questions, and (c) the stimulation of class discussion. The ability to provide experimental experience for the student and to help the student to select his own is rated eleventh out of twelve.

When the results of these studies are compared with the novel features of the new physics curricula specified earlier (p. 39), it is noteworthy that in

Spore's investigation the evaluation of student reaction to what appears to be an open-ended situation is regarded as relatively unimportant; while neither study mentions the ability to organise directed discovery or skill in the use of multi-media learning devices. These are certainly vital skills for teachers working with the new syllabuses. It is also surprising, in view of the research findings previously discussed (p. 11), that neither Farmer's nor Spore's list of teacher competences include such specific teacher acts as clarity of exposition which has been shown to be an important factor in determining student achievement outcomes. An up-to-date specification of physics teaching skills would surely include a number of identifiable verbal skills such as the ability to construct open-ended questions designed to stimulate student thought in a new direction. Farmer's study shows a slight trend in this direction.

As the longest established modern physics course it is not surprising that PSSC should be the subject of several comparative studies. One of these by Petit (1969) is an analysis of teaching behaviours and their effects on student achievements. The behaviour of four PSSC teachers is compared with that of four non-PSSC teachers using three measuring instruments; (a) interaction analysis (a term explained on p. 21), (b) analysis of teachers' questions, and (c) analysis of students' perceptions of classroom activities. Petit reports that the PSSC teachers ask more questions and

spend more time in hypothesising and less time in defining terms. He finds little evidence in either case of real enquiry learning and comments that most orderly talk in the classroom is teacher talk whichever course is being taught. Two criterion instruments of student achievement are used; an attainment test and a 'processes of science' enquiry. The PSSC students are reported as superior at all attainment levels but no significant difference is recorded between the groups on the 'processes of science' questionnaire. This latter result is to be expected in the light of the previous observation that little inquiry seems to take place although the students of the PSSC teachers feel that there is more freedom in the classroom.

A more recent comparative study of cognitive performance of PSSC and non-PSSC students is that of Wasik (1971). Using an achievement test instrument which it is claimed is not biased in favour of either strategy, the author reports that when general scholastic ability is covaried out, the PSSC students' performance is significantly better than that of the other students in items which involve analytical skills but inferior in knowledge items. Wasik cautions that in both cases though significant the differences are small and concludes that they may be due to the PSSC students having spent more time than the others in developing analytical skills and less time than the non-PSSC group on activities likely to encourage the learning of knowledge. Since

both groups spent the same time in learning this seems a plausible explanation. Among other process-product studies of the effects of new physics courses are these of Mackay (1971) which are discussed later (p. 69 & p. 73).

The research of Petit and others has shown that one of the chief effects of the introduction of modern physics curricula is a change in the verbal behaviour of the teacher. The new strategy puts the physics teacher in a new role compelling him to interact with the students in a different way, verbally and otherwise. A number of studies recently carried out have paid close attention to the verbal style of the science teacher. Investigations of this kind include these of Snider (1965), Sharp (1966), La Shier and Westmeyer (1967), Cook (1967) and Pancratz (1967). Some of these studies are considered in more detail later in the text.

There are three different methods of identifying a teacher's verbal style. The first is an observational technique in which what the teacher actually says to the class (and perhaps also what the students say to the teacher), is recorded at the time of speaking, either by having an observer present in the classroom or by tape recording the lesson. The teacher's statements are then classified and coded. These are 'low inference' procedures. An observation procedure of this kind is used in the research being described here.

Alternatively the teacher's verbal style may be assessed by eliciting his students' perceptions by means

of a questionnaire or interview. Jungwirth (1971) reports a study in which eleventh grade biology students are asked to comment on some aspects of their teacher's style. A third method that might be used depends upon the teacher's self-perception of his own style. The use of both of these 'high inference' techniques to provide a "teacher's image" is discussed by Jungwirth and Tamir (1973), who suggest that in the case of the students' perception of the teacher's image, the measure represents the class-mean of student perceptions and may therefore be more reliable than that based on the decisions of one or two neutral observers. They point out, however, that the use of teacher self-assessment, as expressed for example in interview, may be hazardous since the teacher may not always behave in the way he says or thinks he does.

One aspect of the present research concerns a comparison between sharply contrasting verbal teaching styles of physics teachers when teaching a modern physics syllabus.

CHAPTER 3

EDUCATIONAL OBJECTIVES AND THEIR EVALUATION

INTRODUCTION

Specific aspects of teacher behaviour are frequently of interest in the context of an evaluation study where it is desired to find how effective a new teaching programme has been. Are the teachers' aims being achieved? Are the goals specified for the students being reached? In studies of this kind it is important to pay attention to what the teacher thinks the students should be learning. It is this concern with learning goals that leads to the concept of the educational objective. Bloom, Hastings and Madaus (1971, p. 8) point out that education is a process of change and that it is the function of education to bring about desirable changes in the students.

In setting out the aims of the course the curriculum innovator should consider how the terminal behaviour of the students will be changed as a result of taking the course. Furthermore it is important that as far as possible the changes that do occur in the learner should be desirable changes. It is perhaps inevitable that any teaching programme however carefully considered will result in some undesirable changes in the students. The changes

desirable or otherwise which do occur are unlikely to affect all students equally. The extent of change will be related to individual differences among the learners in ability, enthusiasm, interest, motivation and so on. An estimate of this variation in expected changes is one of the central aims of any evaluation procedure. Bloom, Hastings and Madaus (1971, p.8) state that "...evaluation... is the systematic collection of evidence to determine whether in fact certain changes are taking place in the learners as well as to determine the amount or degree of change in individual students."

If it is accepted that education implies changes in individuals and that some such changes are desirable and some not, this raises the question of what is desirable and what is not. Similarly if some learners are more susceptible to certain changes than others, the question must be asked: what changes are possible? It is the implicit purpose of all teaching acts to promote changes in the learner. Consequently, any evaluation of the effect of teacher behaviour must be concerned with measurement of some of these changes. To specify in verbal terms a series of desirable, and in the circumstances, possible student changes is to state explicitly the goals of the education process. These goals are called educational objectives.

EDUCATIONAL OBJECTIVES

Mager (1962,p.3) says that, "An objective is an intent communicated by a statement describing a proposed change in a learner - a statement of what the learner is to be like when he has successfully completed a learning experience." He contends that educational objectives must not only be stated in behavioural terms so that the outcomes can be measured but that the conditions under which the behaviour will occur must be specified. In other words a minimal performance is described. It is the view of many such writers that to be useful an educational objective must be specified in terms that requires the student to demonstrate that he has achieved the objective. The range of specificity with which objectives may be expressed is demonstrated by contrasting: 'To be familiar with Newton's law of universal gravitation' and 'The ability to apply Newton's law of universal gravitation to compute data about satellites in orbit around the Earth'. In the first instance it is not clear how 'familiarity with the law' is to be judged; the terminal behaviour is not stated. Evaluation of objectives is difficult where there is a lack of precision about the terminal behaviour that is expected to result.

In writing about the variables in discovery teaching, Glaser (1966) points to the distinction between learning by discovery as a teaching technique and learning by discovery as a behavioural objective.

He shows that there are two things which characterise discovery as a teaching process. Firstly, it involves the inductive process in which the learner establishes concepts and principles by generalising from experience of specifics. In physics a student measures the quantities of momentum for different parts of a physical system at various stages of the interaction of one part with another, and eventually becomes aware that the total quantity of momentum of the whole system is not affected when different parts of the system exchange momentum with one another. The second aspect of discovery learning Glaser calls 'errorful learning' meaning that inevitably the student will spend much time exploring blind alleys and may not in fact discover what it is intended he should discover but instead discover something different. Glaser goes on to argue that in many learning situations the objective specified requires a certain level of performance and that this level is most effectively achieved in a situation where the student has to respond with increasing precision as he heads towards mastery, i.e. towards attainment of the educational objective specified for him. Glaser does not regard the discovery method as being appropriate in the attainment of this kind of objective, and suggests also that teaching of associations may not require inductive or errorful learning. On the other hand he agrees that where the objectives are concerned with establishing rules and principles, inductive learning is more appropriate.

Glaser concludes that the discovery method of teaching is likely to be more successful in helping the learner to reach some objectives than others. It is interesting to note that Glaser considers it likely that "...discovery behaviour is specific to the subject domain in which discovery takes place". This would seem to indicate that if 'learning to discover' is an objective specified for a science course its achievement by a student does not mean that he is likely to be proficient in discovery in some other area; say, when researching for a television programme on a matter of current public concern. On the other hand it is conceivable that the learner who has acquired the habit of looking for conservation laws in physics may find this habit helpful in a non-scientific context. It is noticeable, incidentally, that taxonomies of educational objectives in science rarely include discovery as a terminal behaviour.

Cronbach (1966, p. 90) points out that discovery teaching may not be suitable for all students and suggests that perhaps the successful response of individual students to the discovery method depends more on personality than on ability. If Cronbach is correct, then an important independent student variable, namely student personality, has been omitted from the present study. The decision to exclude this aspect was taken on grounds of uncertainty about the identification of the appropriate personality factors.

Cronbach avers that there is need for long term

research into the consequences of discovery teaching on a range of outcome variables (pp.88-90) some of these are behavioural objectives such as 'Application' which he describes as "...the ability to solve problems where the discovered rule is relevant"..., others relate to wider changes in the intellectual style of the learner such as 'Rationale' which Cronbach defines as "Understanding of the consistency between this principle and other concepts in the discipline". Such outcomes are referred to in this thesis (p. 53) as educational objectives in the cognitive domain. Cronbach also includes among his outcome variables objectives such as 'Interest' described as "Concentration or voluntary effort at the time of training", and 'Valuation' or "Enduring interest, desire to study in the field, appreciation of the value of knowledge in the field". These latter objectives are regarded here as being in the affective domain (p. 53). In so far as the present investigation has been successful in identifying contrasting styles of physics teaching which exemplify the discovery and didactic methods, the results reported in chapters 6 and 7 may be expected to add to the existing state of knowledge of outcomes of these teaching styles, since the dependent variables of this study are included in the range of outcome variables specified by Cronbach as being among the criteria by which discovery teaching should be judged.

It might be argued that there is an essential



contradiction between the specification of a terminal behaviour in the form of an educational objective and the open-ended approach of discovery teaching. It should not be overlooked, however, that observation of open-ended learning behaviours may lead to the identification of objectives which are those sought by the learner when placed in the open situation. Unfortunately, this process can lead to a situation in which what happens is taken to be what ought to happen. A realistic appraisal of the dilemma leads to the conclusion that objectives must be so formulated that different learning strategies can be employed in reaching them.

A taxonomy of educational objectives.

The need to specify the educational goals for the learner and to communicate these goals makes it important that any strategy which facilitates these processes is utilized to the full. Bloom et al (1956) classify educational objectives which involve intellectual tasks into a taxonomy of objectives, while Krathwohl, Bloom and Masia (1964) do the same for objectives which deal with feelings and attitudes. Such classification helps to remove the confusion and ambiguity which often surround the formulation of educational goals and hence greatly assists communication. These writers specify three broad areas in which change or development of the learner occurs as objectives are reached. These areas are called domains and the three domains identified and described by

them are; (a) the cognitive domain, (b) the affective domain, and (c) the psychomotor domain. In this classification system educational objectives are regarded as being in the cognitive domain when their achievement means that the students have developed intellectual skills or abilities: for example, the ability to solve a quadratic equation. Objectives concerned with changes of attitudes on the part of the learner, such as an increase in awareness of, or liking for a subject are called objectives in the affective domain. These latter objectives are concerned with feeling or emotion and show the extent of acceptance or rejection of a commitment to a policy or to a set of values.

In the taxonomy of objectives for each of these domains the objectives are set out in a hierarchical order. In the cognitive domain Bloom et al propose a taxonomy which classifies cognitive objectives into six categories:

1. Knowledge: the ability to recall specific facts, of terminology, of conventions, of trends, of classifications and categories, of criteria, of methodology, of principles and generalisations, of theories and structures.
2. Comprehension: the ability to translate presented material into a more meaningful form, interpretation and classification.
3. Application: the ability to apply a scientific or social science principle to concrete problems.

4. Analysis: the ability to break down the elements of the presented material, recognising their relations and organisation.
5. Synthesis: the ability to synthesise elements and parts to form a whole.
6. Evaluation: the ability to evaluate in terms either of internal or external criteria.

Described in this way educational objectives specify in operational terms the required terminal behaviour of the learner. The subject content, however, is not indicated so that to be useful in a subject context such objectives must be interpreted by the subject specialist in precise subject terms. For example, it is the task of the linguist to decide what is mean by 'application' in the learning of a language.

The detailed taxonomy of Bloom and others sub-divides each category into more specific categories and indicates examples of test items that might be used in the evaluation of each. It can be argued that there exists within each category an internal structure or hierarchy in the sense that, for example, the recall of specifics is less complex than the recall of theories and structures. The hierarchical order of the main categories is also primarily one of ascending complexity from knowledge to analysis, synthesis and evaluation (called by Bloom the 'Highest Abilities'). Knowledge is placed lowest in the hierarchy because the

others depend on it. Before knowledge can be interpreted or a principle applied the knowledge or principle has first to be recalled or recognised. Objectives which represent more complex intellectual tasks are above those which represent straightforward thinking processes.

In the affective domain Krathwohl, Bloom and Masia (1964) state this taxonomy of objectives:

1. Receiving: an awareness and willingness to receive or recognise a stimulus and later to become selective in attention.
2. Responding: compliance as a result of a stimulus, willingness to respond and displaying satisfaction as a result of response.
3. Valuing: display of attitude which recognises the value of belief, a willingness to be identified with it and a commitment to the belief.
4. Organisation: seeing how a value held relates to other values and building the framework of a value system, so that a consistent set of values results.
5. Characterisation by a value or value complex: the individual acts consistently within his developed value system and is able to revise his value judgments in the light of new evidence so that a consistent overall philosophy of life develops.

Here, as in the cognitive domain the objectives form a hierarchy which represents the development of attitudes from the level of bare awareness to the point where they form a consistent set of deeply held values

which may guide or control a person's actions. The learner has to receive a stimulus before he can respond to it so that 'responding' is above 'receiving' in the hierarchy. Again, these objectives are expressed in a content-free way. As with the cognitive domain each category is divided into sub-categories which themselves constitute a progressive development of attitude. These categories and sub-categories along with illustrative examples are described by Krathwohl, Bloom and Masia.

Student development in the cognitive and affective domains are evaluated in the present study using educational objectives of the type discussed above, specified in terms of physics, (chapters 6 and 7). Among the objectives evaluated are several which may be considered to straddle the boundary between the cognitive and affective domains. It could be argued that 'objectivity learned from physics' has a cognitive component in that such an awareness probably requires a measure of analytical thinking for its foundation.

The third domain not so far discussed, the psychomotor, is regarded by Bloom and his collaborators as "... the manipulative or motor skill area". There exists at the present time no detailed taxonomy of objectives in this domain and student development in the psychomotor area is not considered in the present study.

EDUCATIONAL OBJECTIVES IN SCIENCE

Early studies of attainment in school science used the method of factorial analysis. Pawley (1937) carried out an investigation into the abilities involved in the learning of chemistry by 16 year old grammar school boys. He identified three factors; (a) a general intelligence and verbal ability factor, (b) a spatial factor, and (c) a practical factor which he regarded as being not mechanical. Berridge (1947) found that in learning mechanics and hydrostatics four factors were important: the ability to reason by analogy, verbal ability, number ability and spatial ability. On the other hand Jog (1955), who studied the factors underlying the ability of Form V grammar school boys to learn physics, considered that the general intelligence factor is by far the most important. Among other minor factors Jog identified a verbal factor as well as one which he described as 'practical-mechanical-spatial' in a study which was not concerned with practical work. Two investigations of factors entering into the ability to learn biology, by James (1951), and by Lamb (1954) both regarded a "g" or general intelligence factor as being the most important factor identified although Lamb reported that in his case a large part of the variance was unexplained by any factor. In all these studies the tests used were tests of student attainment of abilities connected with rote learning and the recall of specifics.

The first sign of concern about the narrow range of abilities being tested in science was a report of the Science Masters Association (1938) which pointed to two main components of scientific ability; the 'acquisition of scientific information and knowledge' and the 'development of scientific modes of thought'. This second aspect of scientific ability was related not to knowledge but to scientific method and an important investigation carried out by Keeslar (1945) resulted in a list of ten elements of scientific method validated by the judgments of practicing research scientists. This list was then refined to produce a list of the elements of scientific method suitable for school students. Keeslar concluded that the elements of scientific method are definite and are recognised by scientists. It is interesting to note that Keeslar's elements of scientific method ante-dated much of more recent thinking by being expressed in behavioural terms.

Among the behaviours included in scientific method are some which Burke (1949) regards as specially important as outcomes of science teaching and, quoting Dewey, goes on to identify an ability which he calls 'critical thinking'. Burke argues that it is possible to define in operational terms what is meant by critical thinking and maintains that such a definition permits tests of critical thinking to be constructed. The fifteen behaviours regarded by Burke as being exhibited by a person with ability in critical thinking in

physics are all stated in behavioural terms and include (a) 'Criticises faulty deductive reasoning', (b) 'Selects data which are pertinent to a problem', and (c) 'Recognises what assumptions, beyond the data, have to be made in the formation of hypotheses'. These abilities would be classified in the taxonomy on p. 53 as among the 'Highest Abilities'. Burke omits the formulation of a hypothesis and the devising of experimental procedures from his definitive list. He regards these as creative and not critical abilities. He makes the point that critical thinking must be a prescribed outcome for science teaching and emphasised the importance of making an effort to overcome the difficulty inherent in the construction of test instruments for this purpose.

Mary Burmester in 1952 also refers to the earlier work of Keeslar in a study which involves the identification of skills required in scientific thinking and the definition of appropriate behaviours. Starting from the elements of scientific method proposed by Keeslar she derives a list of behaviours consisting of eight main categories of ability, each of which is sub-classified. These are:

- " 1. Ability to recognise problems.
2. Ability to delimit a problem.
3. Ability to recognise and accumulate facts related to the solution of a problem.
4. Ability to recognise a hypothesis.
5. Ability to plan experiments to test hypothesis.

6. Ability to carry out experiments
7. Ability to interpret data.
8. Ability to apply generalisations to new situations."

Nedelsky (1949) in a notable paper discusses the formulation of objectives in the physical sciences. He specifies three factors as being vital in curriculum design:..."the objectives to be achieved, the subject matter or content to be taught, and the method of instruction to be used." Like Burke and Keeslar, Nedelsky also emphasises the desirability of an explicit statement of objectives and gives as reasons: (a) guidance in choice of content and of learning experiences, (b) help in test construction, and (c) communication between teachers and students, between teachers and teachers and between teachers and evaluators. In his paper he contrasts two methods of arriving at the formulation of objectives. The first method is to state the general objectives for a course, to move in to the more specific objectives in terms of expected student behaviour and finally to select subject matter and teaching methods designed to achieve these specific objectives. Nedelsky's second procedure starts from a consideration of what the subject is and allows the behavioural objectives to be thereby defined. Physics has to do with subjecting theoretical predictions to experimental verification. Therefore the ability to test theoretical predictions against experiment is a terminal behaviour.

He argues that both methods are necessary. The idea of a two dimensional content-objective grid described later in this thesis (chapter 6, p.151) is suggested by Nedelsky who draws an interesting distinction between topics of two kinds: one which is important in itself; and one which has the purpose of assisting the student to acquire (for example) the ability to 'select data which are appropriate' - for which purpose another topic would have served just as well.

In specifying what amounts to a taxonomy of behavioural objectives for physical science, Nedelsky points out that behavioural objectives, no less than content topics, must be classified for a physical science course.

Nedelsky's list of objectives may be summarised as:

1. Knowledge: of laws and principles, of theories, of facts, of technical terms, symbols, units, dimensions, etc.; of relations or patterns in science; of the nature and structure of science.
2. Ability to use the methods of science: in abstract situations; in "academic" situations new to the student, and in situations outside the classroom.
3. Ability to read scientific literature: to read a book or long article; to read a passage; to interpret tables, graphs, drawings, etc.
4. Proper attitudes and habits: proper estimation of; the value of data; the power and value of science; the

value of experiment or observation; a tendency away from prejudice or preconception and towards habits of thorough learning.

A comparison of this taxonomy with the general taxonomy described earlier (p. 53) reveals a remarkable similarity in many respects. The first two categories listed above correspond closely to the knowledge and application categories previously stated. The ability to read scientific literature incorporates in part some of the higher abilities of analysis, synthesis, and evaluation; while Nedelsky's fourth category is partly in the cognitive and partly in the affective domains of the more general taxonomy. Ability to use the methods of science in abstract situations corresponds directly to category B specified for the Scottish physics syllabus (p. 146) and is one of the objectives evaluated in the present investigation. Situations which Nedelsky defines as new to the student and outside the classroom (sub-classifications of his second category) describe precisely the category C objective, also a subject of interest in this study (see chapter 6). The Nedelsky category relating to habits and attitudes is concerned in part with the attitude evaluation undertaken here and described in chapter 7.

Nedelsky concludes his paper by describing five criteria for formulating objectives:

1. Communicability: they must be stated unambiguously.
2. Importance: they must be important by consensus view of experts.

3. Teachability: they must be feasible in the learning situation.
4. Testability: they must be capable of being evaluated.
5. Comprehensiveness: all important objectives must be included.

These criteria are markedly similar to the ones specified by later writers and discussed previously in this chapter. It seems clear that much of the recent development in the field of educational objectives must be attributed to the pioneering work of Nedelsky in physical science. Certainly the basic structure of the educational objectives with which the present investigation is concerned derives directly from his work.

This review of the development in science education of an awareness of the importance of specifying course objectives started with a discussion of early attempts to find a factor common to achievement in science using factor analysis. It is therefore appropriate to conclude by referring to an investigation carried out by Lewis (1967) in which he used objective tests in physics, chemistry and biology designed to measure student attainment of cognitive educational objectives as well as tests of numerical, verbal and spatial ability. A factor analysis showed that a general scholastic achievement factor was linked to the lower cognitive abilities such as knowledge and application. There seemed to be also an aptitude or reasoning factor comprising spatial and numerical ability associated with student attainment of the higher cognitive objective

of evaluation in all three sciences, but especially in physics. Lewis found that while the learning factors concerned with attainment of objectives classified as knowledge, comprehension and application in the taxonomy of Bloom et al (p. 53) were similar this was not so for objectives classified as evaluation. The results of Lewis' study reinforce the decision taken to attempt to investigate separately the attainment of the higher abilities - categories C and D in the Scottish taxonomy (p. 146). This decision was taken despite the difficulty reported by Lewis and others of making clear cut distinctions between the objective categories ascribed to test items; a difficulty encountered in the present study and discussed further in chapter 6 (p. 162).

EVALUATION OF EDUCATIONAL OBJECTIVES IN SCIENCE

Formative and summative evaluation.

Most workers concerned with formulating educational objectives have stressed the importance of specifying objectives so that the expected terminal student behaviour can be evaluated. Nedelsky (1949) points out that the evaluation of abilities in physics, such as the ability to apply empirical generalisation to specific phenomena, may depend both on the principle and on the phenomenon chosen in the test situation. Where this is so the reliability of a test comprising items of this sort is doubtful. It is generally agreed that educational objectives provide a focus on the goals of educational

strategy and may influence that strategy. Bloom, Hastings and Madaus (1971,p.20) explain..."that evaluation should be both formative and summative in its scope." These writers argue that making this distinction helps to bring the "evaluation process closer to the teaching and learning processes". The purposes of summative evaluation are to establish a rank order among students, to judge the effect of the teaching and to allow curricula to be compared. It is a terminal evaluation procedure and should take place at the end of the teaching and learning processes. Formative evaluation is intended to determine the extent of mastery by the students and help to pinpoint difficulties for the teacher. Such evaluation procedures must occur during the teaching and learning process so that the results can lead to improvements in the teaching and learning strategy.

Which kind of evaluation is intended should influence the kind of test instrument employed. Where formative evaluation is attempted the test describes the degree to which the testee has attained some specified criterion performance. Such tests are called 'criterion-referenced'. Tests used in summative evaluation relate the testee's performance to the performance of a reference group and are called 'norm-referenced' tests. The attainment tests used in the present study and detailed in chapter 6 are essentially summative both in scope and in purpose. They are 'norm-referenced' tests. This matter is discussed by Bloom, Hastings and Madaus (1971,pp.91-92).

Evaluation in the cognitive domain.

Attainment of educational objectives in the cognitive domain may be evaluated in one of three ways as Nedelsky (1967,p.132) points out: by using (a) oral tests, (b) written tests, and (c) performance tests. As a test instrument, although flexible and penetrating, the oral test is notoriously unreliable due often to the personal interaction effect between tester and testee. In discussing performance tests in science Nedelsky (pp.145 et seq) warns of the difficulties that observation of the student's performance introduces. He concludes that performance testing should only be resorted to when the course objectives cannot be evaluated in any other way. Neither oral or performance tests are used in the research being reported here.

This leaves the written test as the only instrument available in the present circumstances. There are two main groups of written tests of student achievement; (a) the objective or fixed-response test, and (b) the essay or free-response test - to use the description due to Ferris (1960). As Ferris and others, including Houston (1970,p.38), show the use of the term 'objective' is unfortunate. An objective test is one in which the marking (scoring) process is objective in so far as the marker is not allowed to exercise judgment in marking. To quote this author..."it is only the marking process of an objective test which is objective. The decision about the correct answer is a matter of

subjective judgment on the part of the writer of the item, as is the decision about which items from those available will be used in a particular test.... Only the marking process is objective and it is this objectivity of marking which distinguishes objective testing from all other forms of testing."

The same author goes on to say that...."tests consisting of objective items are also objective in another sense. Because the accepted answers are agreed upon in advance it is possible to construct these items so that to obtain the correct answer the candidate must exercise one or more abilities in physics."

"Where these abilities are represented by educational objectives, the candidate in answering the items correctly shows that he has developed these abilities. The test is therefore a tool which is being used to evaluate the achievement of desirable objectives. It is however, wrong to suppose that only objective items - in the sense of those which have marking objectivity - can be used to evaluate educational objectives. Any type of examination can do so, if it is devised with this task in mind...."

"Whichever type of test is used,...it must evaluate educational objectives which are deemed to be important...it is merely easier to use objective testing to evaluate accurately a specified list of objectives. The term 'objective test' is misused when taken to indicate a test which evaluates objectives. An 'objective

test' is one in which the marking process is not subjective, that is all."

Houston goes on to discuss the benefits and limitations of objective testing for educational evaluation in science; a matter also discussed by Ferris who in indicating that free-response tests have a place in evaluation of objectives, warns that such tests, although apparently easy to construct, may well be unreliable unless a structured analytical marking procedure is used.

These writers and others also stress the importance of test validity. Ferris describes validity as the extent to which a test actually measures what it purports to measure and points out that "Validity implies some criterion outside the test itself which serves as a basis for comparison". A test which is reliable without being valid is consistent in its measure of the wrong quality.

In describing how objective tests may be employed in the evaluation of the attainment of cognitive objectives a number of other writers, among them Dunning (1949), Kruglak (1966) and Nedelsky (1967, pp.81-117;149-184) also emphasise the need for test criteria based on item data derived from adequate pretesting procedures. These writers emphasise the need to have regard for test reliability and validity. The validation procedures applied in the present study for tests of attainment in the cognitive domain are

described in detail in chapter 6.

A number of recent investigations are concerned with student evaluation in the cognitive domain; some of these, such as that of Comber and Keeses, are referred to elsewhere in the thesis. A notable study is that of Mackay(a)(1971) who describes a longitudinal study of 271 physics students in secondary schools in Victoria, Australia, during a two year study of physics. Using objective tests consisting of multiple choice items Mackay reports that over the period student scores show significant gains in the achievement of cognitive objectives concerned with:

- (i) the development of certain cognitive processes such as 'the ability to make logical predictions based on a model'
- (ii) the development of understanding of the nature of physics, and
- (iii) the development of qualitative understanding of fundamentals of physics, and ability to apply knowledge to unfamiliar situations.

Mackay's findings are confirmed by those incidentally obtained in the study being reported here (p.176).

Evaluation in the affective domain.

In their comprehensive treatise on formative and summative evaluation of student learning Bloom, Hastings and Madaus (1971, pp.225-245) deal with evaluation techniques for affective objectives. They discuss some of the reasons for neglect of affective outcomes and

list among them fear of indoctrination and the belief that attainment of such objectives may take many years. Rejecting such anxieties Bloom, Hastings and Madaus dispute in particular the belief that attainment in the affective domain is a long term goal and aver that many affective objectives can be achieved in the short term. It perhaps ought to be stressed that some such attitudes may as quickly be lost - a point made elsewhere in this thesis.

These writers, admitting that affective evaluation has many difficulties not encountered when cognitive evaluation is being attempted, go on to describe methods of evaluating affective outcomes. Among the techniques reviewed in that work are; (a) the use of interviews, (b) open-ended questioning, (c) the use of questionnaires consisting of attitude scales, which may be constructed in several ways. These include the semantic differential technique described by Osgood, Suci and Tannenbaum (1967); and the method of summated ratings devised by Likert (1932).

The advantages and disadvantages of interviewing as a data-collection technique are discussed in chapter 5. Its use in gathering information about affective outcomes of science teaching is restricted by a number of factors. Amongst these is the difficulty of persuading the student that he is not being orally examined and graded. Where the student suspects this he may tend to respond in a favourable manner and conceal

his true feelings. This problem is overcome to some extent where the interviewer follows a detailed interview schedule, which specifies the questions asked, and perhaps also lists a set of fixed responses to each question. When this procedure is used interviewer bias is less likely to distort the situation. Selmes (1969) reports an experiment in which a group of 12/13 year old students were encouraged, in the absence of their teacher, to talk freely about their attitudes to school science. The discussions were tape-recorded and subsequently transcribed. From an analysis of the transcripts Selmes concludes that a stereotype of a scientist exists in the students' minds and that they show little knowledge or sympathetic understanding of the work of scientists or of science as a method of investigation.

The open-ended question which requires the respondent to answer by writing a statement does not appear to have been used very frequently as a tool in the evaluation of student attitudes to science, although its use in the measurement of attitude structure and socialisation is widely recorded.

A third method of affective evaluation not mentioned by Bloom, Hastings and Madaus is that of direct observation of student behaviour. This, being a low inference method, may be thought to be the most reliable. Here the development of attitude is judged by changes in student behaviour. Enthusiasm for science is measured by the extent of the student's involvement in

science-based hobbies or attendance at a school science club, or by the choice of science subjects beyond the stage at which they are compulsory. One of the important disadvantages of this technique is the fact that many unobserved variables may operate. A student enthusiastic about science may be unable to attend meetings of a school science club because of some financial or domestic commitment. On the other hand another student may opt to continue with science subjects for reasons unconnected with his liking for science; such subjects may be essential for entrance to a chosen career not directly related to science.

The most prominent measuring instrument used to evaluate affective development is unquestionably the attitude questionnaire. The use of questionnaires in attitude measurement and the construction of attitude scales is fully discussed by Oppenheim (1966). Writing about the techniques of attitude scale construction, Edwards (1957,p.9) claims that "A well-constructed attitude scale consists of a number of items that have been just as carefully edited and selected in accordance with certain criteria as the items contained in any standardised psychological test". The attitude scales constructed and used here in the fashion described in chapter 7 consist of items (statements) intended to estimate the intensity of affective response by requesting the student to indicate the strength of his agreement or otherwise with each statement. Such

attitude scales, called Likert scales, are discussed by Oppenheim (1966, pp.133-143). Their use in this research is described in detail later (pp.193-9).

Ormerod (1971) describes an investigation into affective development in science and in student awareness of the social implications factor. Ormerod uses Likert scales consisting of 12 and 8 statements respectively on a five point scale to measure; (a) liking of science as a school subject and (b) the social implications of science for 500 boys and girls (ages 13-14 years) of the upper level of ability. He reports that when student scores in (a) and (b) above are compared with the number of science options the student makes, the subject scores are more strongly linked with the number of options than are the social scores. When boys and girls are considered separately it is found that while for boys there is no significant relation between scores on the 'social implications of science' scale and the number of science options there is a significant relation in the case of girls.

One inherent weakness of Ormerod's study, confessed by the author, is the pooling of schools in the sample since different schools operate different constraints in the choice of subject options offered.

Another study in which Likert scales are used is that of Mackay (1971) involving Australian secondary school students taking a two year course in PSSC physics. The aim of the investigation is to evaluate

affective changes in the students during this time. The four objectives measured here are:

"1. The student should come to view physics as an important activity for himself: he becomes committed to actively searching for an understanding of physical phenomena and gains enjoyment thereby.

2. The student should come to view physics as an open rather than a closed process which is by its nature dynamic, creative, tentative and unfinished.

3. The student should view scientists as normal, active, fallible human beings who are different only in the area of their special training.

4. The student should view the process of physics learning as a non-authoritarian situation in which students are stimulated to think about physical phenomena, encouraged to 'discover' physical relationships for themselves and to participate in the development of experimental and theoretical methods for solving problems."

The attainment of each of these objectives is measured using a scale consisting of 10 statements administered at different stages in the study - a research design somewhat similar to that employed in the present study and described in chapter 7, where some of the results of Mackay's study are further discussed.

Another study by Mackay (1970) into teacher characteristics affecting student changes on PSSC objectives makes use of a Likert scale to measure

teacher attitudes about the physics course. Teachers' responses are correlated along with other teacher data against their students' scores from the evaluation of affective changes in students carried out by the same researcher and commented on earlier (p. 73). In this way Mackay identifies teacher characteristics which seem likely to promote development in the affective domain. None of the teacher behaviours investigated by Mackay is related to that studied here: verbal teaching style. It must be remembered too, that the method Mackay employed to identify teacher behaviours - questionnaire - deals only with what teachers say they do and not with what actually happens in their classrooms.

A recent study by Gardner(b)(1973) into personal and environmental influences on student attitudes to physics uses an instrument consisting of eight scales. Each scale relates to a need selected from the Activities Index of Stern (1958). This index, derived from the needs-press model propounded by Murray (1938), is an instrument identical in format to a Likert scale. Some of Gardner's findings using the needs-press scales are considered in chapter 7 (p. 225).

CHAPTER 4

PRELIMINARY INVESTIGATION

INTRODUCTION

The changes in school physics teaching accompanying curriculum development in physics over the past decade have two aspects.

The first is an extensive change in syllabus content intended to take account of a massive development in the field of physics knowledge since 1890. As Kahn (1962) points out, scientific investigation presupposes a conceptual framework accepted by the scientific community. When current scientific problems cannot be resolved within the accepted paradigm, a "scientific revolution" occurs and as a result a new framework emerges inside which the current problems can be resolved. The forty years from 1890 - 1930 was a period of scientific revolution.

By 1925 the long standing ideas of classical physics had been extended by Einstein's theories of special and general relativity, Bohr's quantum theory of atomic structure, and Heisenberg's theory of wave mechanics. In the 1930's the fundamental concepts of nuclear physics were established. Yet until 1960 physics was still being taught in schools as though these developments had not taken place. The new physics syllabuses, among them the Scottish physics syllabus came into existence.

around this time and show that attempts have been made to rectify this omission. As Barr (1966), writing about the aims of physics teaching in Scotland says, "Today's child is born under a satellite, grows up with transistors and will be cursed or blessed by the nuclear atom. We cannot continue filling his head with dull and dated facts... we must give him some basis for a rudimentary understanding of modern scientific developments and for appreciating the relevance and place of science in his life and in society."; or Maddox (1966) who, in describing the aims of Nuffield Science stated that "... in the late fifties ... many ... were concerned with the quality of education and had become dismayed by the static character of the... curriculum. For those were still the days of Nicholson's hydrometer, the density bottle and Helmholtz galvanometer." Maddox asserts that ... "too little was being taught about the new and more exciting developments in physics...".

The second factor was the radical change in the methodology of teaching the new material. The old method was based on teacher demonstrations of routine experiments the main aim of which was to confirm a previously specified relation between physical quantities. These experiments were often described by the teacher in the form of detailed dictated notes: the experimental emphasis was on obtaining results corresponding as closely as possible to the expected

values. On the other hand the new syllabuses are designed to be accompanied by a teaching methodology which stresses pupil experimentation. Pupils are expected to discover for themselves the operational concepts of physics in open-ended learning situations. They then report their findings in their own words. As Ritchie (1970) says "The approach in secondary therefore progresses towards the Heuristic as the pupil grows older... The discovery approach is stage-managed in the early years and then the props are gradually removed until the individual pupil is left largely on his own towards the end of the course." This new methodology represents a move in science teaching in the direction of discovery learning and away from the traditional expository learning method. The two learning methods have been contrasted by Glaser (1966) and are discussed here (p. 27). A recent statement on the techniques of teaching physics appears in Lewis (1972). Here it is said that although "There is no single best way of teaching... There is, however, an identifiable atmosphere in a classroom in which physics is being learned, no matter what teaching technique is being applied. In most classes like this the teacher is not telling the students by lecturing nor probing students' minds by questioning but is himself thinking out loud and drawing students' thoughts along. His questions invite their participation, his statements challenge their intelligence, his handling of chalk and apparatus is such as to demand student involvement in his own thoughts. When this is achieved

physical facilities, equipment, texts and even the syllabus become mere auxiliaries and the human interaction between teacher and students is the central operation of the learning process."

This research is concerned with the methodological contrast between open-ended discovery learning and the direct instructional sequence used by the expository teacher. If the ... 'human interaction between teacher and students is the central operation of the learning process'... then it should be possible to specify this open-ended-expository dimension in terms of a technique which describes the classroom interaction between teacher and students. Various interaction analysis techniques are referred to elsewhere. The one used here is the ten category system of Flanders (1970) described in Chapter 5 (p. 99).

The variables which might affect student achievement include several observable and identifiable teacher behaviours. This investigation is concerned with one of these, namely that of the prevailing style of verbal interaction between teacher and students, and its effect on student achievement of cognitive and affective educational objectives in physics.

EXPERIMENTAL VARIABLES

In Chapter 1 the possible factors are discussed that might conceivably be important in determining student achievement in science. In this investigation

the identifiable variables chosen are:-

- 1) Teacher variables:
 - (i) Verbal style as identified by an observational technique of classroom interaction analysis.
 - (ii) Qualifications.
 - (iii) Years of teaching experience.
- 2) Student variables:
 - (i) Intellectual style as measured by IQ scores.
 - (ii) Social status as indicated by father's occupation measured on a scale of occupational prestige.
 - (iii) Sex.
- 3) Learning conditions variables:
 - (i) Type of school
 - (ii) Size of classes in science
 - (iii) Type of area served by the school
 - (iv) Level of provision of text books, laboratory assistance, apparatus, etc.
 - (v) Total number of hours per week spent studying science.

Recent research has indicated that some of these variables may be decisive in influencing student attainment in science.

Comber and Keeves (1973) in their report on the International Association for the Evaluation of Educational Achievement investigation into science education in nineteen countries contend that in the case of fourteen-year-olds the most important factor

in accounting for variation in achievement in science between students from different schools is the home background of the students. They also state that the provision of ancillary laboratory staff is important in countries where practical work is emphasised. The evidence on the effect of teaching methods and textbook provision is on the other hand contradictory as between countries.

In that part of their report on students in their final year of secondary schooling, Comber and Keeves report that achievement in science may tentatively be related to such variables as type of school, provision of ancilliary staff and whether the science teachers have been trained. At this level there is little evidence to support the idea that teaching techniques based on discovery methods are superior to those based on drill methods.

Their investigation did not indicate that size of class or size of school were important factors associated with attainment levels in science.

James, R.K. (1972) in comparing group and individual instructional techniques in science found that except in the case of a course on 'a knowledge of the methods and aims of science' where the class taught by the individual strategy performed better, there was no significant difference in cognitive attainment brought about by the two instructional techniques.

Recent studies by McIntosh and Mackaill (1971) in the achievement of 17-18 year old boys and girls in

Scotland on an advanced one year course found that while there was no statistically significant difference between the sexes in the case of chemistry, the girls achieved significantly better grades in physics than the boys. On the other hand, in the international study already referred to, Comber and Keeves found that for all countries, boys showed a more favourable attitude to science than girls and also displayed evidence of greater achievement. They also found evidence to suggest that this sex difference in attainment increases with age.

Cropley and Field (1969) discovered evidence to suggest that there seemed to exist cognitive variables in addition to IQ but more indicative of intellectual style than of intellectual level and contend that these additional variables may influence science achievement.

James and Pafford (1973) found no significant difference in achievement between the children of professional fathers and those of non-professional fathers either in 9th grade general science or in physics at 12th grade. It was suggested, however, that since many children of non-professional fathers were low in science achievement farther down the school and thus did not continue with science, the children of non-professional fathers in the study were a very highly selected group. On the other hand, Lavin (1965) commenting on research findings of investigations into socioeconomic status as a determinant in the prediction

of academic performance, concludes that social status is usually found to be positively identified with attainment at High School and quotes the work of Bresee (1957); Coster (1959); Travers (1949) and others. At the same time this writer points out that where the sample includes students from the very top social classes these findings are apt to be reversed. He goes on to discuss the research of Davis (1956) and others who found this to be the case and suggests that this inconsistency may be explicable in terms of social values and motivation to achieve academic success.

The studies of Campbell (1971); Ivany and Oguntanade (1972); Snider (1965); and Tisher (1968) were specifically concerned with verbal aspects of the teaching mode and their effect on science achievement. Campbell found that Junior High School students taught for a period of one year by teachers whose verbal style was 'indirect' showed significantly more favourable scores on both a scale of scientific attitudes and in a scientific curiosity inventory than did students taught in a 'direct' way. Flanders' i/d ratio was used in identifying teachers' verbal styles. The same result was obtained in respect of a test of cognitive attainment in science. Ivany and Oguntanade in their study of the explanatory style of 14 High School physics teachers by analysing the verbal communication through which teachers interpreted physics to students, found that about 80 per cent of all teacher utterances could be classified as lecturing and that less than 10 per cent

were related teacher questioning or responding to students' ideas. This finding is broadly confirmed by the findings of Snider (1965) and Tisher (1968).

The research design used in the present investigation required that the teacher variable related to verbal style be considered the independent variable and that all the other background variables also enumerated above be controlled as far as possible. It is realised that there may be many other teacher behaviour variables which are important; several of these are referred to earlier. It is clear that the teacher's verbal style is not necessarily characteristic of his total behaviour in the classroom: it may not even be the most important aspect of teacher behaviour. Nevertheless, in the writer's opinion it is a central feature of the teaching strategy, a view shared by Lewis (1972, p. 79). The investigation described here is an attempt to relate a particular aspect of verbal teaching style to the discovery-expository dichotomy in physics teaching and to assess its effect on student outcomes.

EXPERIMENTAL CRITERIA

Consideration of the aforementioned variables leads to a range of criteria to be employed in setting up the investigation.

Certain criteria were specified in the selection of (1) a local authority area, (2) schools within that

area, (3) teachers of physics within these schools, and (4) pupils taught by these teachers. In each case the criteria employed are stated as are the methods of applying them.

1. Local authority area.

A local authority area was sought within daily reach of Edinburgh since much of the field work involved visiting schools in the area to observe lessons. It was considered preferable that the area chosen should be large enough so that all investigational work could be carried out in the schools of only one local authority. This was desirable for two reasons. Since the provision of text books, apparatus and ancilliary assistance such as laboratory technicians is a local authority matter it is probable that the level of provision in these matters among schools will be similar. This would not necessarily be so between schools in different local authority areas. Approval of the Director of Education was necessary before headmasters and physics teachers in the schools concerned could be approached and asked to co-operate in the study. It might have been difficult to obtain approval for an investigation the results of which could invite comparisons among schools under the jurisdiction of different local authorities.

When these matters had been carefully considered an area was selected which it was hoped would satisfy the criteria specified for schools, physics teachers and students. With the prior written approval of the Director

of Education, head teachers in all secondary schools in the area which seemed likely to meet all these criteria were approached and asked to allow a request to be made to their physics staff to co-operate in the study. In every case except one the physics teachers concerned agreed to participate after discussing the matter fully with the investigator. Subsequent investigation showed that the area initially chosen adequately fulfilled the criteria set down for schools, teachers and students.

2. Schools

A. School facilities. In order that comparisons between students in different schools be not vitiated by differences between schools in such learning conditions variables as textbooks, apparatus, etc. schools selected were such that the level of provision in these respects was similar.

B. Type of area served. As one of the student outcomes it was proposed to investigate was changes in students' attitudes towards physics, it was felt that schools involved in the study should serve a mixed community which would be neither totally rural or totally urban, since environmental factors in pupils lives outside the school might influence student attitudes to physics. In an industrial area student attitudes towards physics would be reinforced in some cases by parental involvement in especially a science based industry. On the other hand, in an essentially agricultural

community a different cultural emphasis would manifest itself in the students' homes and this might be less favourable to physics. It is often said that one of the reasons for the claimed lower achievements of girls in science is their awareness of a different social expectation. It would seem likely therefore that social factors of this kind should be equalised as far as possible among schools. The schools selected here are all considered to be similar to one another as regards catchment area. Each contains within its population students from both urban and rural communities.

C. Staffing provision. In a longitudinal study it is essential to ensure as far as possible that the experimental conditions will remain fairly stable during the proposed period of the investigation - in this instance three years. It was important therefore to select schools which were not subject to an abnormally high turnover of physics teaching staff.

All the above criteria in respect of area and schools were applied by making judgments, in collaboration with Her Majesty's School Science Inspectors about the area and schools within the area that had been provisionally selected. In relation to staffing provision, however, three data-based criteria were also used. These were for each school:

- ✱ (i) Mean Number of candidates for 'H' grade physics in 1970 per physics teacher.
- ✱ (ii) Mean Number of candidates for 'O' grade physics in 1970 per physics teacher.
- ✱ (iii) Mean Number of physics teachers in 1970

(✱ Data provided by the Scottish Certificate of Education Examination Board and by the Scottish Education Department on a confidential basis.)

These data (i), (ii) and (iii), for all schools in Scotland, were compared with data for schools in the area in which it was proposed to carry out the study.

D. School academic record in physics. As one of the outcome variables proposed in the study was student achievement in the Scottish Certificate of Education Ordinary grade examination in physics in 1973 it was considered appropriate that schools involved should in the recent past have had a record of success in the national examinations in physics which did not vary much from one school to another and also that each school should have had a success rate close to the national average. For this purpose the success rate in 1970 of schools in the area selected was compared with that of all schools in Scotland. The details of performance criteria used were:

- ✱ (iv) Mean percentage pass rate in S.C.E. 'O' grade physics in 1970, and
- ✱ (v) Mean percentage pass rate in S.C.E. 'H' grade physics in 1970.

(# These data were provided by the Scottish Certificate of Education Examination Board on a confidential basis.)

The criteria specified above in relation to schools were employed to ensure that findings should be as widely generalisable as possible and not restricted to particular circumstances.

3. Teachers.

When the criteria applied in the selection of a local authority area and of schools within that area were satisfied the group of teachers from which would be drawn the teachers involved in the study was therefore defined. It remained to be seen whether there existed within the schools in the area selected a group of physics teachers who would satisfy the criteria specified for teachers. These are set out below.

A. Range of verbal teaching styles. It was an essential part of the research design to study a spectrum of different verbal teaching styles ranging from physics teachers whose verbal style implied a teaching strategy which was heuristic and open-ended to those whose verbal style seemed to be identified with a teaching mode dogmatic and expository. A list was compiled of all physics teachers who had agreed to participate in the study and visits arranged to watch each teacher of physics who seemed to meet the other teacher-criteria to establish whether there existed in that area an adequate range of teaching styles. Nine teachers in

seven schools were observed by the author teaching a variety of physics lessons to students in Third Year, that is fourteen-year-olds. All classes in this and other parts of the research were mixed boys and girls.

Flanders' system of interaction analysis in the classroom was used in the way described in chapter 5. Prior to recording these visits the experimenter had practised using the appropriate coding technique for a total period of approximately eight hours as recommended by Flanders (1960). This practice was carried out by observing teachers and students not involved in the experiment.

As a result of these preliminary visits, of the original nine teachers one was excluded from the study at this stage because it was felt that he was unsuitable since his level of class control was so low that it seemed inadvisable to attempt to speculate about his style or to measure student achievement outcomes. Of the eight physics teachers remaining, on the basis both of an interpretation of interaction analysis scores and of a subjective judgment by the experimenter, two teachers were regarded as being very open-ended in their verbal mode and two as being extremely expository in style. The remaining four teachers were estimated to occupy intermediate positions on the spectrum of styles thus established. Two of these teachers subsequently transferred to posts in other areas and so were excluded from the study at an early stage. Details of

the interaction analyses data relating to this part of the experiment are displayed in Tables 2 and 3 (p.115).

In order to check the extent to which teachers described as extreme in the study merit this description in the country as a whole, interaction analysis data were obtained for two reference teachers who, in the opinion of the experts, are exponents respectively of the most open-ended and of the most expository styles of all physics teachers in the country. These data are also shown in Table 6 (p.124).

B. Years of teaching service. It seems probable that on entering teaching some teachers at least will change over the first few years and develop their style as they gain in confidence and professional expertise. As the design of this experiment assumed a fairly stable teaching profile over a period of three years it was decided to exclude from consideration any teachers of less than five years teaching service.

C. Training. Since all secondary school teachers in Scotland are required to attend a full-time course of teacher training before entering service in schools all teachers in the area satisfied this criterion. None admitted to having heard of interaction analysis during their period of training.

D. Qualifications. All teachers in the study are graduates who include at least two recognised graduating courses in physics in their curriculum vitae; this being the minimum requirement for the

teacher to be awarded a qualification allowing him to teach physics in a Scottish secondary school.

4 Students.

The identification of schools and teachers automatically identified also the pupils concerned in the investigation; six classes in the schools concerned were so identified; 150 students in all. This number was reduced to 100 by the end of the investigation.

The requirements of the experimental design meant that students involved in the study were to be taught by the same physics teacher for a two year period. Headmasters of the schools were asked to give an assurance that as far as possible classes would be organised so that this requirement was fulfilled during the main part of the investigation.

The following criteria were specified for students concerned in the investigation.

A. Homogeneity of IQ scores. When the student groups had been defined an IQ score was obtained for each student from the school records. This referred to a test taken by the students in their primary school at aged 11 years. For students who had attended a primary school outwith the area in which the research was carried out an IQ score was not usually available. Since much research has indicated that IQ is a significant variable in predicting student achievement the attainment outcomes of such students were not included in the subsequent analysis.

To permit comparisons to be made of attainment outcomes between the six student groups steps were taken to estimate the degree of homogeneity in respect of this variable. Where homogeneity was suspect, differences were taken into account in the statistical procedures adopted in the analysis of outcome data. Details of those procedures are discussed in chapters 6 and 7.

B. Homogeneity of social status. In the same way as in (A) above, data were obtained about the father's occupation of all students in the study. These data were obtained by asking each student to describe his father's occupation in a special form supplied. Where the written description of occupation was considered to be inadequate for the purpose of classification, students were asked verbally to supply further details. Each student was then classified according to the social status of father's occupation as indicated by the Hall-Jones Scale of Occupational Prestige for Males, Hall and Jones (1950).

As social status is also regarded as an important variable in relation to educational achievement it was also considered necessary to take steps to ascertain the extent of homogeneity between student groups in this respect. As before, where the level of homogeneity of social status was shown by statistical analysis to be below prescribed levels this variable was also controlled in the analysis of data related to student achievement.

C. Common course. Since it is generally assumed that syllabus content is an important factor in determining achievement it was considered essential that all students in the study be following a common course in physics so that a valid comparison could be made at the conclusion of the experiment between different student groups as regards attainment levels. It was also considered desirable that the students should be following a modern syllabus so that the findings would be widely applicable in the future.

Since all students in the investigation were following the Scottish physics syllabus (p. 36) it was considered that this criterion was satisfied.

D. Appropriate age range. It was decided that the students participating in the study should be in their Third and Fourth Years (ages 14 - 16 years) of secondary schooling during the period of the investigation. Students in First and Second Years were rejected on the grounds that the science studied in these years is not examined at Ordinary grade and consequently all students at that stage do not follow a common course.

Students in Fifth and Sixth Years were also rejected because it was felt that teachers often feel constrained to lecture to such students on the grounds of their greater maturity. Consequently the spectrum of teaching styles might have been much narrower.

CHAPTER 5

ASSESSMENT OF VERBAL TEACHING STYLE

INTRODUCTION

One aspect of the science teacher's verbal style amongst those various aspects discussed in chapter 2 which it is appropriate to study at the present time is that which might seem to link the discovery learning versus expository teaching dichotomy with recent curriculum developments in science of the kind outlined also in chapter 2. A teacher whose verbal interaction with the class includes asking lots of questions in such a way as to stimulate the students to think for themselves; one who prompts his students to explore experimental situations in an open-ended way and generally to exploit fully the learning situations he has devised for them, is likely to be more in line with the discovery mode of science teaching which is at the core of Nuffield and other modern science syllabuses than a teacher in the expository mode. Sutherland (1970) in contrasting Nuffield physics teaching with Traditional physics teaching for 12 and 13 year olds found that for students of above average ability, Nuffield teaching led to greater understanding of physics concepts than did traditional teaching methods. He observed that 'The Nuffield students struggled hard throughout the discovery process to formulate their findings in a strictly scientific way'.

Barr (1966) writing about the Scottish Physics Syllabus states that "...certain experiments are intended to be of the 'open-ended' type, not just in the senior classes but well down the school. In these there is no final 'conclusion'; one answer found leads to the raising of another question to be solved by further experiment and critical judgment is called for. Imagination and initiative are encouraged in the use of apparatus and the design of suitable experiments to solve a problem: indeed pupils may be encouraged to produce their own theories, explain observations, test these by experiment and revise them. Their attention will frequently be drawn to the limitations of their theories, their experiments and apparatus, and the value of an experiment that fails will be pointed out.....".

By contrast, the expository dogmatic teachers verbal style must be predominantly a lecturing style. He will speak for long periods to the class, telling them about science, instructing them carefully before allowing them to engage in any practical work, ask questions which require only a closed response from the students and will, in general, control the verbal behaviour of the class quite closely.

Invertasch (1968) in a study involving Junior High School students found that there was no significant difference either in achievement or in attitude between a group of students using a teacher-directed methodology of problem-solving in science and another group who being

self-directed used their own methodology of problem-solving. Marin (1968) compared the performance of two groups of High School physics students, one group given an open-ended laboratory course and the other a laboratory course closely directed by the teacher. He found that when tested in (a) understanding of physics concepts, (b) laboratory performance, and (c) problem solving achievement; there was no significant difference between the groups.

In this investigation an attempt has been made to identify skilled teachers of each of these verbal teaching styles as well as teachers whose verbal styles appear to be intermediate between these extremes.

The principal instrument used in this identification is the well known procedure for analysing classroom behaviour described by Flanders (1970). In the present research teachers are placed on a continuum according to how the verbal component of their activity varies between open-ended (indirect) and expository (direct). In classifying teachers' verbal style in this way two assumptions are made.

(i) The aspect of verbal style thus identified is content free. That is, a teacher's style in this respect is not dependent upon the physics topic or kind of lesson taught. It is assumed that a teacher who is expository in presenting a new topic to his students will display the same basic style as he would if discussing examples in a problem-solving class. Since it was not practicable to

observe different teachers dealing with the same topics in this investigation the validity of this assumption was tested by the reliability of the observational data for the same teacher on different occasions: see Tables 4 and 6.

(ii) The teacher's verbal style as recorded for episodes during a verbal interaction between the teacher and the class as a whole is a significant component of his total verbal style, and is characteristic of that style. This would appear to be a dubious assumption since a much closer personal contact arises during student experimental work between the teacher and a small student group or between teacher and individual student.* In the present investigation such interactions were not recorded; not because they were considered to be unimportant but merely because of the impossibility of doing so without disturbing the learning environment to such an extent as to risk distorting or inhibiting what was taking place. In the investigator's experience the general noise level in the classroom at such times is high whilst teacher and students converse in general in a low voice when the teacher is discussing their experimental work with a small group. For this kind of interaction the teacher is usually in close physical proximity to the students. Attempts were made early in the investigation to record such episodes but after subsequent discussion with the teachers these attempts were discontinued.

* In actual fact, there is a relatively small amount of small-group interaction.

MEASURING INSTRUMENTS (1)

1. Classroom observation.

The procedure used is the ten-category system known as the Flanders Interaction Analysis Technique. This technique requires the observer in the classroom to record the verbal activity of teacher and students. Every three seconds, or more frequently if the character of the verbal behaviour changes, he notes which category best describes the verbal behaviour during that period. The result is a continuous record of these parts of a lesson (or episodes) which have been recorded. The final tally of numbers may then be analysed either in terms of the relative frequencies of different kinds of teacher and student verbal behaviour or by using a two dimensional matrix system of interpretation. Because of statistical problems related to the interdependence between one category, the next category to occur and the one preceding it, Flanders (1970) recommends this system where mechanical data processing facilities are at hand since the matrix display allows a search to be made for recurring interaction patterns between teacher and students. Since interaction analysis was being used in this research to identify teachers' styles it was thought to be less important to study interaction patterns and the method of analysis of relative category frequencies was judged to be adequate.

Each of the ten categories is described below. The first seven represent teacher talk, categories 8 and 9

represent student talk while category 10 is a residual category.

Category 1: (Accepts feeling). The teacher accepts and clarifies an attitude or the feeling tone of a student. The teacher may sometimes predict or recall the feeling.

Category 2: (Praises or encourages). Teacher talk which praises or encourages student action or verbal behaviour. Teacher joking to release tension but not at the expense of another student. It includes gestures which aim to encourage the student.

Category 3: (Accepts or uses students' ideas). Teacher clarifies or extends ideas put forward by a student. Initial teacher extensions of students' ideas but excluding teacher's own ideas.

Category 4: (Asks questions). Teacher asks a question about content or procedures based on the teacher's ideas with the intention that the student should answer. Rhetorical questions are excluded.

Category 5: (Lecturing). Teacher addresses the class or part of it stating facts or opinions about content or procedures. The teacher is expressing his own ideas giving the teacher's explanation or citing an authority other than a student.

Category 6: (Giving directions). Teacher gives directions, orders or commands with the intention that the student will obey.

Category 7: (Criticising or justifying authority). Teacher talk intended to alter student behaviour from unacceptable

to acceptable behaviour; teacher reprimands student; teacher explains his own action to the class; extreme self-reference.

Category 8: (Student talk-response). Student talk which is in response to teacher's initiative. Student answers teacher's questions or responds to the teacher's invitation to comment on a situation within the framework suggested by the teacher.

Category 9: (Student talk-initiation). Talk by students which is initiated by them. The student asks the teacher to explain a topic outwith the immediate structure, or develops his own opinion or line of argument.

Category 10: (Silence or confusion). A residual category which includes short periods of silence or periods of confusion during which there is no identifiable verbal behaviour.

Ground rules

While using this procedure in the present investigation the following ground rules were observed:

1. No periods of continuous category 10 were recorded for longer than one minute.
2. Where there was doubt about categorising a particular episode the prevailing balance of teacher initiative or teacher response was taken into account.
3. Where more than one kind of behaviour occurred inside a three second period both were recorded since it is desirable to maximise information by recording a shift of emphasis from teacher-talk to student-talk or from teacher-initiative to teacher-response.

There are several ways in which the tally of relative category frequencies can be analysed depending on which aspect of the interaction is of central importance. Some of these are described below.

(1) Ratio of student talk to teacher talk: This is calculated from the ratio of total frequencies within categories 8 and 9 to the total frequencies within categories 1 - 7 inclusive. This index gives an estimate of the dominance of the teacher since a teacher who monopolises the talking time most probably controls the dialogue.

(2) I/D ratio: This index is described as the ratio of total frequencies within categories 1+2+3+4 to the total frequencies within categories 5+6+7. This ratio, like the one following, provides information about the balance of teacher initiation (5+6+7) and teacher response (1+2+3+4). A teacher who frequently uses categories 5, 6 and 7 is said to be teaching in a 'direct' style. He is lecturing or directing the students. On the other hand, a teacher who makes more frequent use of categories 1,2,3 and 4 and relies less on categories 5,6 and 7 is regarded as teaching in an 'indirect' style. The verbal style of such a teacher involves questioning the students, responding to their replies and encouraging further student ideas. He is letting some of the initiative in the learning situation pass to the students. The I/D ratio is intended to reflect the classroom climate resulting from the balance

between 'indirect' and 'direct' teacher influence. Flanders (1964) wrote that by 1958 it had been established that "...all teachers employ a combination of statements, some that restrict freedom of participation and some that expand it. Given an extended period of observation, a fairly stable proportion of balance of indirect and direct statements can be identified for each teacher."

3. i/d ratio: This index is similar to the I/D ratio. It is the ratio of total frequencies within categories 1+2+3 to the total frequencies within categories 6+7. Since most teacher talk occurs in categories 4 and 5 an i/d ratio may consist of very few tallies and can become abnormally and possibly adventitiously large when only a few short visits are made to observe a particular teacher. The i/d ratio is, however, sometimes preferred to the I/D ratio because it is less dependent on subject matter.

4. Teacher question ratio (TQR): This index indicates the tendency of the teacher to use questions in dealing with subject content. It is the percentage of category 4 and 5 statements which is classified as category 4. That is $TQR = \frac{4}{4+5} \times 100$. It usually involves a high proportion of the total teacher talk recorded which would seem to increase the reliability of the score. It is a measure of one aspect of the teachers' verbal style but ignores data which may be strongly characteristic of the teachers' overall verbal

style such as his response to students' ideas (category 3).

Flanders and Simon (1970) concluded, after reviewing research reported between 1960 and 1966 into teacher effectiveness, that this factor in the interaction pattern of students and teacher is directly related to student attitude and achievement outcomes. Rosenshine (1970) reached the same conclusion after reviewing process-product studies reported before 1970.

5. Teacher response ratio (TRR) is a measure of the teachers' tendency to respond to the ideas and feelings of the students. It is compiled by adding the frequencies of categories 1, 2 and 3 and dividing by the sum of categories 1+2+3+6+7 and expressive as a percentage.

Thus $TRR = \frac{1+2+3}{1+2+3+6+7} \times 100$. As in the case of the I/D ratio it excludes the most frequently occurring categories 4 and 5 and may therefore be erratic for short observation periods.

All of these indices can be obtained from the final tally of relative frequencies of categories and do not depend on the matrix form of data display mentioned earlier.

Consideration of the indices described above shows that the I/D ratio and the teacher question ratio seem most likely to distinguish between the verbal styles related to extremely open-ended and to extremely expository teaching modes according to the argument

developed in the introductory part of this chapter. It was thought to be expedient to make use of indices of teacher influence which had been generally recognised and used by other researchers in similar studies so that comparisons could be made. The I/D ratio had been used in this way by Lashier (1965) and Wragg (1973) whose research is discussed elsewhere in this thesis.

Table 1 shows a tally of relative category frequencies for a lesson observed during the preliminary stages of this investigation.

TABLE 1

Typical relative category frequencies for observed lesson.

Category	1	2	3	4	5	6	7	8	9	10	Total
Frequency	Nil	13	27	203	283	62	30	157	12	230	1017

Specimen calculations for:

I/D ratio:

$$I/D = \frac{1+2+5+4}{5+6+7} = \frac{0+13+27+203}{283+62+30} = \frac{243}{375} = 0.649$$

TQR ratio:

$$TQR = \frac{4}{4+5} \times 100 = \frac{203}{486} \times 100 = 42\%$$

Advantages of the Flanders interaction analysis technique.

(1) It has been established since about 1960 and has been shown to be a useful technique in identifying a range of important aspects of teacher style and of describing teacher-class interaction at all stages of schooling.

(ii) It is easy to learn to use.

(iii) It has been used in many other studies of the effect of science teacher behaviour variables on attainment and attitude outcomes, such as the work already commented on in this thesis and the recent work of Wragg (1973) who studied the classroom behaviour of 100 graduate student teachers of many subjects including physics. Wragg obtains an I/D ratio of 0.27 for 21 542 tallies from 37 physics lessons. He reports that observers found the Flanders system difficult to use in this subject because of the laboratory nature of the lessons. He describes how the usual lesson structure in science to some extent dictates the verbal interaction patterns observed regardless of the teacher's style.

The recurrent use of the Flanders interaction system in other studies permits ready comparisons to be made between their findings and those of this investigation.

(iv) The categories are defined in such a way that the extent of direct teacher influence may be estimated from observation data in a straightforward manner.

(v) The system is reputed to give high cross-observer reliability between trained observers. Holroyd (1973) however, reporting on the observation of teachers in technical education cites reliability coefficients between observers of only 0.53 using Scott's coefficient calculated in the manner described by Flanders (1960) who declares that a Scott coefficient

of 0.85 or higher should be attainable. In the above observation of technical teachers Holroyd obtained I/D ratios ranging from 0.16 to 0.43.

(vi) The Flanders system yields data in matrix form so that if required, recurring verbal interaction patterns may be identified.

Disadvantages of Flanders interaction analysis technique.

(i) Some of the categories such as 1 and 2 occur very infrequently in physics lessons. In this study only 16 tallies in category 1 and 169 in category 2 were recorded in a total of 32,030 tallies for the six teachers principally involved in the study.

(ii) Only one category is used for teacher questions (category 4) so that the system does not permit a distinction to be made between questions allowing the students to give only a narrow specific answer and more 'open' questions which allow the student to give a wide and perhaps unpredictable answer.

(iii) Category 5 (Lecturing) covers both didactic teacher talk which answers students questions and that which is initiated by the teacher. In these cases (ii) and (iii) a clear distinction between these two kinds of teacher talk would help to sharpen the distinction between the 'direct' and 'indirect' teacher.

(iv) The Flanders system has three categories for the teacher responding in a positive way to the students' feelings, behaviour or ideas (categories 1,2 and 3 respectively) yet only category 7 may be used to describe

teacher's negative reaction to students. This category does not allow a distinction to be made between criticism of a student's intellectual efforts and of his general conduct in the class.

The limitations of the Flanders system referred to above led to the development of other systems, some of which are discussed here (pp.108-9). Most of these later systems consist of more than 10 observer categories. Such a system is the 16-category developed by Hough (1967) and called the Observational System for Instructional Analysis. It is designed to parallel the Flanders system so that 9 categories are used to describe teacher talk, three to describe student talk and four to specify silence or non-functional behaviour, compared with 7, 2 and 1 respectively in the Flanders system. Among the modifications of the Flanders system made by Hough were -

- (a) a sub-classification of Flanders category 5 to distinguish between teacher-initiated lecture and teacher answer to student question.
- (b) a sub-classification of Flanders category 7 to distinguish between teacher criticism of student work and criticism of a more personal kind.
- (c) a sub-classification of Flanders category 9 to distinguish between student-initiated questions and statements, and,
- (d) a sub-classification of Flanders category 10 which allows periods of different conditions of productive silence to be distinguished from confusion and other unproductive behaviour.

It also allows ratios to be computed which are descriptive of direct or indirect teacher influence. In a study of verbal interaction patterns of High School physics teachers Pancratz (1967), using Hough's classification system, rated 32 physics teachers according to three factors; (a) a rating by the school principal of the teacher's personal adjustment and teacher-pupil relationship, (b) the teacher's ability to respond to teaching situations in accord with educational theory as measured on the "Teaching Situations Reaction Test" and (c) the students' perceptions of the teacher's all-round teaching ability as recorded by the average class score on a student inventory. The five teachers rated most effective on the basis of these three criteria taken together used significantly (0.01 level) more 'indirect' teacher influence and less 'direct' teacher influence than the five teachers rated lowest on the aforementioned criteria. Unfortunately this study did not involve measurement of student outcomes.

MEASURING INSTRUMENTS (2)

Teacher interviews.

The interview: Writing about the new approach to educational evaluation discussed in Chapter 1 Parlett and Hamilton (1972) describe "an information profile using data collected in four areas: observation; interviews; questionnaires and tests; documentary and background sources." Writing about the place of

interviews in this research strategy the authors state that "Discovering the views of participants is crucial...". They go on to say that teachers should be asked about their work, what they think of it and so on.

Hadge (1967) states that "the principal application of the interview in social science...is in its use for the purpose of making people talk about themselves". Margaret Stacey (1969) points out that "The aim of any research interview...is to get truthful information from people on a subject about which they are under no obligation to tell, if they do not wish to do so".

Lovell and Lawson (1970) in describing the use of interviewing in educational research explain how the interview may be used (a) in the initial stages of a project to help clarify the problem, (b) as the main data-collection procedure or (c) in conjunction with other techniques to provide supplementary data and/or to clarify the data from another source. In the present study teacher participants were interviewed for this last purpose.

Interviews may be carried out for two different reasons: (a) to find out what the interviewee knows and (b) to seek information about his attitudes, opinions and beliefs. In the first case the information sought is factual and in the second it is subjective. According to Good (1963) interviews may be classified in terms of: (a) function (diagnostic, treatment or research), (b) number of persons participating (individual or group),

(c) length of contact (short or prolonged), (d) roles assumed by the interviewer and interviewee.

Interview techniques: Three main types of interview technique are described in the literature: (a) the structured interview, (b) the unstructured interview and (c) the semi-structured interview. Stacey points out that "There is no hard and fast dividing line between the structured and the unstructured interview. They should be seen as two ends of a continuum". The operational distinction between each type of interview technique is described below.

(a) A structured interview is one in which the questions to be asked by the interviewer have been precisely decided in advance. He will ask all interviewees exactly the same questions in exactly the same order. The wording of the questions is specified. There is no opportunity to rephrase questions or ask additional ones.

Such interviews discourage rapport between the interviewer and his subject - a rapport which is advantageous where it is required to conduct the interview in depth or where the subject's opinions or beliefs are being probed. On the other hand, structured interviews tend to result in standardised data so that comparisons between responses are not affected by differences in interview technique. It might be said that reliability is achieved but possibly at the expense of validity.

(b) An unstructured interview is one in which the interviewer is left completely free to conduct the interview in any way he thinks fit. The questions may be asked in any way and in any order; indeed there may be no preconceived range of questions. The main function of the interviewer is to get the subject to talk as freely as possible around the central topic of interest.

Information gained from such interviews will often go beyond that which might be elicited in a highly structured interview. The main disadvantage of this kind of interview is that data obtained from different subjects by different interviewers or by even the same interviewer on different occasions may not be directly comparable.

(c) The semi-structured interview lies somewhere between these extremes, depending on the degree of rigidity imposed. In this format there may be a list of questions or topics which it is desired to discuss but the precise order in which they are discussed, the depth to which each topic is pursued and the range and scope of supplementary topics is left somewhat to the discretion of the interviewer.

The data from such interviews are necessarily less standardised than those resulting from a structured interview but since the same topics have been discussed with all subjects some comparisons should be possible. As Stacey points out "This kind of interview is particularly useful where experiences, feelings,

reasons and motives are involved."

In the present investigation it was decided to use the semi-structured format for these reasons:

1. Since the interviews were expected to provide data which would supplement that obtained using the observational technique of Flanders it was felt necessary to ensure that the data should be amenable to treatment on at least an ordinal scale.
2. As the purpose of the interviews was to obtain information about teachers' views and opinions as well as to elicit facts about their teaching procedures, an interview strategy which encouraged candour was called for. The highly structured interview seemed unlikely to achieve this end.
3. It is generally recognised by Stacey and others that the completely unstructured interview requires a high level of interviewer skill and considerable experience. Since this experimenter was comparatively inexperienced in the technique of in-depth interviewing it was decided to sacrifice the unarguable advantages of freedom provided by the unstructured interview to ensure that data obtained would contribute usefully to the investigation.

Aims of teacher interviews in the present study.

The aim was to compare the degree of authoritarianism in teacher attitudes with their use of direct or indirect teacher influence in their verbal teaching style as measured using Flanders' interaction

analysis technique of observation in the classroom.

In this statement 'authoritarian' is meant in the academic sense as well as in relation to classroom discipline and order. These two aspects of authoritarianism may or may not be associated in a teacher's general behaviour. The mode of teaching physics of one teacher in this study was not at all authoritarian in so far as he showed sympathy and feelings towards the students in their learning of physics. He used a great deal of indirect influence. Yet he was a martinet as regards student misconduct.

CONSTRUCTION AND VALIDATION OF INSTRUMENTS (1)

Classroom observation.

Flanders' 10-category system described earlier was used throughout this part of the investigation. * During the period of preliminary investigation discussed in chapter 4 data were obtained from two visits to each of nine physics teachers. In each case the teachers were observed on both occasions for a complete physics lesson, a duration of about 80 minutes on each occasion. The lessons were generally on different topics in physics although all classes were in the Third Year (ages 14-15) stage. They were not, however, the students who later became involved in the investigation and whose achievement and attitude outcomes were measured; see chapters 6 and 7.

From these observational data I/D and TQR indices

* The Flanders scale was used in preference to the modified scale by Hough so that data would be directly comparable with that obtained by other researchers in the field of science teaching.

were computed for each teacher. These are shown in Tables 2 and 3.

TABLE 2

I/D ratios for data obtained during preliminary investigation.

Teacher Code	B	C	D	F	G	H	J	K	L
(I) First Occasion	0.179	0.520	0.275	0.168	0.205	0.649	0.498	0.571	0.193
(II) Second Occasion	0.300	0.545	0.361	0.158	0.348	0.543	0.380	0.362	0.139

TABLE 3

IGR's for data obtained during preliminary investigation

Teacher Code	B	C	D	F	G	H	J	K	L
(III) First Occasion	16	39	37	13	37	42	36	41	12
(IV) Second Occasion	26	39	23	10	28	41	35	28	16

In both cases the higher the index, the more indirect teacher influence has been used.

The Spearman rank correlation coefficients between ratios and occasions are shown on Table 4.

TABLE 4
Spearman rank correlation coefficients
between ratios and occasions.

Occasions	(i)and(ii)	(iii)and(iv)	(i)and(iii)	(ii)and(iv)
Correlation coefficient	0.867	0.788	0.898	0.904

All values for rho are significant at the one per cent level, $\text{crit. } \rho = 0.765$. $\rho_{(i)(ii)}$ and $\rho_{(iii)(iv)}$ indicate the reliability of the I/D and TQR ratios respectively; while $\rho_{(i)(iii)}$ and $\rho_{(ii)(iv)}$ show the correlation between the two indices for the first and second occasions. Since the TQR index is derived from the same data as the I/D index a high correlation is to be expected in these latter cases. It was therefore decided that in all subsequent classification of teacher style the I/D ratio would be the only index used. This measure was preferred because (a) it comprises all seven categories of teacher talk whereas the TQR makes use only of categories 4 and 5, and (b) other researchers in studies of science teachers' styles had used the I/D ratio, thus allowing comparisons to be made.

Table 2 shows that I/D ratios recorded at this stage in the investigation ranged from 0.649 to 0.139 for the sample of physics teachers involved in the study. The mean and standard deviation of these scores was 0.355 and 0.165 respectively.

This raises the question of the extent to which this range of I/D scores for the sample teachers is descriptive of the possible range of I/D scores for all physics teachers in the country.

Reference teachers.

To find whether teachers who were likely to be described as extreme in the study merited that description in the country as a whole, it was decided to obtain I/D scores for two criterion teachers who, in the opinion of experts represented respectively the most open-ended and the most expository styles of all physics teachers in the country. As argued here (p. 102) an open-ended style is associated with a high I/D ratio indicating a large measure of indirect teacher influence and an expository style with a low I/D ratio which implies strong direct teacher influence.

Method of selection of reference teachers

After being acquainted with the objectives of the investigation three science H.M.I.'s of the Scottish Education Department were asked to list (a) the most open-ended and (b) the most expository physics teachers in the country. The teacher whose name was on all three lists of open-ended teachers and the one whose name appeared on all three lists of expository teachers were selected as reference teachers.

The permission of the local authority and headmaster of each of the selected teachers was then sought and finally the teachers themselves were asked to

co-operate in the study using the procedure described in chapter 4. Care was taken when discussing the project with the reference teachers to avoid divulging their exact role to avoid the Hawthorne effect.

Each of the two reference teachers was observed on four occasions in the same way as other teachers involved in the study. Flanders data were obtained and I/D ratios worked out for each double period of about 80 minutes duration. These appear in Table 6 (p.124) along with verbal teaching style data for the other six physics teachers who comprise the experimental sample. A comparison between the I/D scores of the reference teachers and these of the sample teachers indicates that the six teachers in the experiment adequately cover the full spectrum of verbal styles.

CONSTRUCTION AND VALIDATION OF INSTRUMENTS (2)

2. Teacher interviews

Construction of interview schedule:

So that the interview will yield the information sought it is generally recommended that first a schedule be drawn up by the interviewer; that this draft schedule be circulated for comment by colleagues and a second draft prepared which should then be pretested on subjects similar to those to be interviewed. The final draft should then be prepared and modified, if necessary, in the light of the pretest experience.

In this case a list of 11 topics was first drawn

up. These topics were selected because it was felt that open-ended teachers would respond to each in an identifiably different way from expository teachers.

Each topic was specified as a statement with which teachers would be invited to express agreement or disagreement during the course of the interview. Care was taken to include some statements which would be agreeable to the expository teachers as well as some which would find favour with the open-ended teachers.

The complete list of 11 topic statements with the anticipated responses of different styles of teachers is given below.

TABLE 5
List of topic statements

Topic No.	Statement	Expected Agreement	
		Open-ended Teachers	Expository Teachers
1.	Pupils learn physics best by doing experiments for themselves.	Yes	No
2.	It is important that students enjoy their physics lessons.	Yes	No
3.	In physics students should be encouraged to ask questions and to explore side issues.	Yes	No
4.	Asking questions of a class is an important aspect of teaching physics.	Yes	No
5.	Physics lessons need to be based on previously specified formal relations between physical quantities.	No	Yes

Topic No.	Statement	Expected Agreement	
		Open-ended Teachers	Expository Teachers
6.	Students are unable to profit from experimental situations in physics presented to them in an open-ended way.	No	Yes
7.	It is impossible to teach physics successfully unless the students do regular formal homework.	No	Yes
8.	Examinations are more of a hindrance than a help in teaching physics.	Yes	No
9.	Students should be taught to write their own notes in physics.	Yes	No
10.	Students should be given much more freedom of choice than at present with regards to curriculum.	Yes	No
11.	One cannot be an effective physics teacher without using authoritarian methods of discipline.	No	Yes

These topics formed the basis of the interview schedule which was next drawn up, discussed with colleagues and revised in the light of their comments. In each case, the central statements listed above gave rise to a series of questions which it was felt by answering teachers would reveal their attitude to the subject of the central statement. That part of the interview schedule relating to Topic No. 1 is given below.

"1. Learning physics by doing experiments.

What is the teachers' attitude to noise and chaos in class? Does he think students are learning under those conditions? Does he prefer to avoid chaos by reducing student experimentation?

What experiments does he think might be done as student experiments in Third Year? Ask about particular ones, e.g. gas laws with medical syringes, the specific latent heat experiment using ice and filter funnels.

Key Question: Does he think that on the whole students learn better by doing experiments for themselves or by watching the teacher demonstrate?"

The complete text of the interview schedule is included as Appendix I.

Validation of interview schedule.

In order to practise technique, test recording equipment and so on an interview, using a penultimate draft of the schedule discussed above, was recorded with a physics teacher not involved in the investigation. This resulted in modifications to the schedule and to the procedure followed in conducting the interviews in order to:

- (i) ensure adequate discussion of all eleven topics specified in the schedule
- (ii) remove lines of questioning which led to no fruitful discussion or which proved to be embarrassing to the subject.

Classroom observation.

All interaction data in the investigation were coded by the same experimenter so that considerations of cross-observer reliability do not arise. All data were coded 'live', no attempt being made to use a tape-recorder. This decision was taken on the grounds that (a) teachers' behaviour might have been affected by the presence of a tape-recorder, experience during teacher-interviews suggests that this would have been so, and (b) 'live' coding allows account to be taken of gestures and the general classroom atmosphere when making coding decisions about categories.

In all instances the experimenter sat in a position in the classroom so that he was out of sight of the students as they faced the teacher. The classroom milieu of a particular teacher varied to some extent from one observed occasion to another. Generally, the topic in physics was different each time, individual students were sometimes absent, the structure of one lesson sometimes differed substantially from another given by the same teacher. Where one lesson may have consisted of a teacher demonstration with subsequent discussion followed by a problem-solving session another may have been mainly taken up by brief teacher-class discussion followed by a prolonged period of student experimentation during which the teacher would move amongst the different student groups discussing

their work with individuals.

For the reasons outlined earlier (p. 98) only interaction episodes involving the teacher with the whole class were coded. The amount of lesson time recorded varied from one lesson to another.

During the two year period of the main element of the investigation four visits were made to each of the six physics teachers remaining in the investigation; two of the original eight moved to posts in schools in other areas soon after the study commenced and therefore played no further part in the research reported here. The remaining teachers were visited twice whilst teaching the students involved in the investigation in Third Year and on a further two occasions one year later whilst they were teaching the same students in Fourth Year. In addition to visiting the schools for these purposes the experimenter made other visits throughout the two year period to administer tests and questionnaires as described in chapters 6 and 7. It seemed that as the investigation proceeded his presence in the schools concerned was having less effect on the class-teacher interaction he had come to observe; although the experimenter (himself an experienced physics teacher) was at no stage aware of a highly contrived situation in the classroom.

Analysis of results

For each visit the I/D ratio was calculated from the tallies of relative frequencies of categories (p. 105).

Table 6 below shows the I/D ratio indices for visits to all six experiment teachers and for the two reference teachers. Also shown for each teacher is the mean I/D index together with its standard error.

TABLE 6

Ratio of indirect to direct teacher influence - I/D ratio index.

Teacher Code								
	X ²	H	K	G	J	L	F	Y ²
	0.962	0.649	0.571	0.205	0.498	0.193	0.168	0.304
	0.719	0.543	0.361	0.343	0.380	0.139	0.158	0.241
	0.862	0.862	0.585	0.565	0.328	0.202	0.260	0.363
	0.735	0.613	0.585	0.366	0.243	0.236	0.356	0.193
		0.847	0.893	0.375	0.264	0.234	0.229	
		0.643	0.833	0.415	0.355	0.165	0.0946	
Mean I/D	0.819	0.676	0.638	0.362	0.345	0.195	0.211	0.275
Standard Error	0.128	0.145	0.135	0.125	0.0915	0.0638	0.0918	0.0891

X² denotes reference teacher

Here the standard error for each teacher score is taken as the standard deviation of all I/D scores for that teacher.

The mean I/D ratio of all scores for the six experiment teachers only is 0.405 and 0.430 when the reference teachers are included, the respective standard deviations being 0.221 and 0.244.

Analysis of variance was used to test differences between I/D means for different teaching styles; taking teachers H and K to represent an open-ended (or indirect) teaching style, teachers G and J to represent an intermediate style and teachers L and F to signify the expository mode of teaching physics.

Table 7 shows the mean I/D score for each style.

TABLE 7

Mean I/D index for different teaching styles.

Teaching style	n	Mean I/D	t
Open-ended	12	0.657	} 6.22 3.10
Intermediate	12	0.354	
Expository	12	0.203	
All	36	0.405	—
F:	—	45.16	

Analysis of variance between and within teaching styles gives F significant at one per cent $F_{0.01} = 5.32 (2, 33)$.

Subsequent analysis between style means using Students 't' with the appropriate standard error Goulden (1952) shows that teaching style I/D means are

significantly different from one another at 0.1 per cent.

$t_{0.001} = 2.82$ for d.f. 2,33 in one-tailed test.

Table 8 shows the aggregate relative frequencies for each interaction category for the six experiment teachers.

TABLE 8
Aggregate relative frequencies for each interaction category.

	Indirect Teacher Talk				Direct Teacher Talk			Student Talk		Residual		
Category	1	2	3	4	5	6	7	8	9	10	Total	
Frequency	16	169	592	3943	10128	2160	723	2345	359	11595	32030	
Percentage	0.02	0.53	1.84	12.31	31.62	6.74	2.24	7.32	1.04	36.30	100	
Total	4720				13011			2704		11595	32030	
Total Percentage	14.7				40.6			8.4		36.3	100	

DISCUSSION (1)

2. Classroom observation

Table 6 indicates that Scottish physics teachers vary over a wide spectrum regarding the relative amounts of indirect and direct teacher influence as indicated by analysis of their verbal styles. It is of interest to compare the overall mean I/D ratio of 0.405 with the mean of 0.355 for the preliminary period of the investigation. The standard error is noticeably higher for the teachers having the higher I/D ratios. The large standard errors in the instances of teachers H and K for example may indicate that teachers who profess an open-ended verbal style are less consistent in the use of that style than are the extremely expository teachers. Not all types of lessons or physics topics allow the teacher to behave in an open-ended way or to use discovery teaching methods. A lesson involving mainly teacher-demonstration using apparatus unsuitable for pupil experimentation will compel the open-ended teacher to behave in a more expository manner than he would do if that constraint were removed. In other words, any physics lesson can be taught in an expository way; only some lessons can be taught in an open-ended way using much 'indirect' and little 'direct' teacher talk. It seems likely, therefore, that the dependence of the teachers' verbal style on lesson content is a function of his rating on the open-ended-expository dimension and the standard errors quoted in Table 6 would seem to bear this out.

The low occurrence of categories 1 and 2 (only 0.55 per cent of total) underlines their redundancy in observation of physics lessons. No particular meaning can be readily attached to the high frequency of category 10 in this experiment since many of the tallies recorded in this category referred to periods of observer uncertainty at the end of coded episodes when it was not clear whether the interaction episode had been finally completed.

It is interesting to compare some characteristics of the interaction data gathered in this study with that of Pancratz in his study of the ten High school physics teachers which was discussed earlier (p. 109).

Although Pancratz, who observed each teacher for a total time of 6 hours compared with 8 hours in the present study, used a different classification system the coded data are comparable in some respects, Hough (1966)

The study by Snider (1965) referred to elsewhere (p. 44) involved the use of the Flanders method of interaction analysis to describe the teacher-pupil interaction in High School physics classrooms. Snider's investigation comprised 17 teachers, each observed for about four hours.

La Shier and Westmeyer (1967) reporting on the study of student teachers of eighth grade biology mentioned in chapter 2 used the I/D ratio to characterise teaching style. The mean I/D ratio reported for each student teacher ranged from 0.223 to 0.903 with an overall mean of 0.545.

Table 9 shows how the data derived from observation of the experiment teachers in the present investigation compare with those of the Pancratz and Snider investigations and with data reported by Wragg (1973) from his recent study of student physics teachers.

TABLE 9

Observation data from comparable studies of physics teachers.

	Houston	Pancratz	Snider	Wragg
I/D ratio based on aggregated frequencies	0.363	0.516	0.255	0.27
Ratio of total student talk to total teacher talk	0.153	0.235	0.244	0.23

The data in Table 9 suggest that in general physics teachers tend to monopolise the talking time but that they vary considerably in the amount of direct teacher influence used. This latter observation may be explicable in terms of the different subject content in each of the studies referred to.

EXPERIMENTAL METHOD (2)

Teacher interviews

All six teachers in the experiment readily agreed to be interviewed and gave their consent to the interviews being tape-recorded. In return they were given an absolute guarantee of anonymity and that the transcripts would not make identification possible. All interviews were carried out in private at the

teacher's school during school hours. Each interview lasted approximately one hour. The complete interview was recorded; there was no switching on or off.

Every interview was conducted by the investigator who in doing so tried to observe these points of technique:

- (a) He tried to work within the constraints of the relationship - by now a fairly friendly one; the interviews were carried out towards the end of the period of investigation.
- (b) An attempt was made to avoid asking about matter of opinion as though they were matters of fact.
- (c) The Interviewer's own point of view on the topics being discussed was suppressed as far as possible, not always successfully.
- (d) To reduce tension - teachers were generally fairly nervous during the initial stages of the interviews - the tape-recorder was kept out of sight.

A complete transcript of all six interviews was obtained, and used in the subsequent analysis; see below.

Several excerpts from the transcripts are included here to give an indication of the mood of the interviews and to show how different teachers responded to a particular topic.

Here are two teachers commenting on noise in the classroom: "I think it is absolutely inevitable that

if you are going to leave the children a certain amount of freedom to find out things for themselves, then you are going to end up with children wandering about comparing results, one group with the other... 'what did you get, I don't get that'... this is all part of learning." and by way of contrast, when asked whether students are learning when it is noisy and chaotic and there is a lot of movement in the class, the other teacher replied: "No, I would think not, I tend to the belief that discipline is the start. If you have not got order in the class you can teach nothing. I think perhaps you could teach the few who have a specialised interest in the subject; who wanted to learn, while others who are there and still have to learn wouldn't pay attention at all."

Asked whether students are taught to write their own record of a physics experiment one teacher said: "Yes, to a greater and greater extent as they go through the school...", whilst another teacher when asked the same question responded:... "I would tend to dictate to them because after all this is the thing to which the child is going to refer..."

On the other hand there was near unanimity on some aspects. When asked what effect the abolition of corporal punishment would have on their daily job as physics teachers, the replies were, respectively: (a)... "in the third year... I would have to find some other way of making sure they did their homework."

- (b) "It would not affect me at all, as long as we had the sanction of expulsion."
- (c) "If it was withdrawn without some other deterrent, I think life would be intolerable absolutely,..."
- (d) "I think I would suffer from it because I use it where vandalistic situations are about to crop up... I think it would be wrong to take it away."
- (e) "Well, I don't have a belt. In my teaching life I have used it very very seldom, I can't see it would affect me very much."
- (f) "I think it could have an effect in that there are pupils in this school, who even with the deterrent of corporal punishment can be an awful nuisance,..."

The complete transcripts for the interviews with the teacher adjudged on that basis to be the most open-ended and with the teacher adjudged to be the most expository are included as Appendix II. They provide a contrast between the attitudes of a physics teacher enthusiastic about modern methods of teaching the subject and a teacher who believes that he should adhere to traditional methods.

Analysis of results.

Each complete interview transcript was broken into eleven parts; each part representing that teacher's response to a single topic.

Three experts, two of them science H.M.I.'s of the Scottish Education Department and the other a well

known educational psychologist who had been concerned with planning this part of the study were asked separately to rank the six teachers according to the extent to which they considered each teacher agreed with each of the eleven topic statements. A sample of the instructions attached to each topic is shown below. The general instructions sent to experts about the ranking procedure are shown as Appendix III.

Topic No. 1

Please rank teachers on a scale 1-6 according to the extent to which you think they agree that "pupils learn physics best by doing experiments for themselves".

Mark the teacher who you think agrees most as 1 and the teacher who you think agrees least as 6.

Code	T2	T10	T16	T24	T31	T35
Rank						

Each teacher's response to each topic was scrambled and coded so that experts could not identify the responses of a particular teacher to different topics.

When all six teachers had been ranked for each of the eleven topics by each expert, the ranks allocated by the experts were summed for each topic and teacher to form a summation matrix of ranks.* This is shown in Table 10 where for example the summation ranking for teacher H on topic number 1 indicates that he was ranked 2nd by expert 1, 1st by expert 2 and 1st by

* Where appropriate ranks were reversed before summing.

expert 3. Thus the sum of ranks for that teacher on that topic $R_j = 2+1+1 = 4$ the entry in the summation matrix.

TABLE 10
Rank order summation matrix for all experts.

Teacher Code						
Topic No.	H	K	G	J	L	F
1	4	9	5	16	17	12
2	12	4	14	15	5	13
3	8	3	11	16	17	8
4	5	6	15	7	17	13
5	8	7	16	9	6	17
6	12	13	9	7	8	14
7	10	6	18	10	4	15
8	9	4	17	12	5	16
9	4	5	13	14	17	10
10	12	16	12	5	12	6
11	4	18	9	13	7	12
Σ	88	91	139	124	115	136

It was considered that the task assigned to the experts of making impression judgments about interview transcripts was such that to require judgments on an interval scale would be unreasonable. Attempts at assigning marks to essays marked against a criterion have been investigated by Cast (1939) and (1940) who found that the reliability of such marks was low when one marker was compared against another. Much research has shown that where the scale is reduced to an ordinal one

so that only rankings are required the reliability of the measurements is greatly increased. A consequence of the decision to rank the interview data is that they must be analysed using non-parametric statistical tests; see Siegel (1956, p.18 et seq).

To find a measure of the relation among the three experts' rankings of the six teachers' responses, the Kendall coefficient of concordance W is used. W expresses the degree of agreement among experts about their rankings for each topic, Siegel (1956, p.229).

The Kendall coefficient of concordance is calculated for each topic using the data from the summation matrix. A specimen calculation in respect of topic number 6 is given below.

Specimen calculation.

expert	H	K	G	J	L	F
1	6	4	1	5	2	3
2	4	5	2	1	3	6
3	2	4	6	1	3	5
R_j	12	13	9	7	8	14.

$$\sum R_j = 63 \text{ and } \frac{\sum R_j}{N} = 10.5$$

$$W = \frac{S}{\frac{1}{12} k^2 (N^3 - N)}$$

$$\text{where } S = \sum (R_j - \frac{\sum R_j}{N})^2$$

k is number of judges and
 N is number of teachers.

so that $S = 40.5$, giving $W = 0.257$.

The significance of W was tested by reference to a table of critical values of S (Siegel, Table R, page 286). In this case S was not significant at the 0.05 level ($S_{0.05} = 103.9$ for $k=3$, $N=6$).

Table 11 shows W for each topic with the appropriate significance level for each.

TABLE 11

Coefficient of concordance W for each topic.

Topic No.	1	2	3	4	5	6	7	8	9	10	11
W	0.975	0.746	0.911	0.835	0.721	0.357	0.886	0.949	0.848	0.556	0.771
S	153.5	117.5	143.5	131.5	113.5	40.5	139.5	149.5	133.5	87.5	121.5
Significance level	0.01	0.05	0.01	0.01	0.05	n.s.	0.01	0.01	0.01	n.s.	0.05

n.s. denotes not significant at 5 per cent.

The data shown on Table 10 were reduced to a rank order matrix for the nine topics having W significant at five per cent or less. To express the agreement of the three experts considered as one about their overall rankings of teachers on all nine topics, the Kendall coefficient concordance was calculated from the data in the rank order matrix shown below - Table 12.

TABLE 12

Rank order matrix for all experts based on summation matrix - Table 10.

Topic No.	H	K	G	J	L	P
1	1	3	2	5	6	4
2	3	1	5	6	2	4
3	2.5	1	4	5	6	2.5
4	1	2	5	3	6	4
5	3	2	5	4	1	6
7	3.5	2	6	3.5	1	5
6	3	1	6	4	2	5
9	1	2	4	5	6	3
11	1	6	3	5	2	4
R _j	19	20	40	40.5	32	37.5

The significance of W was tested as before. In this case the value of $S = 478$ giving $W = 0.337$ was significant at 1 per cent. ($S_{0.01} = 441$, for $k = 9$, $N = 6$)

Another summation matrix was constructed for the nine topics which are shown in Table 11 to have W significant at 5 per cent or less indicating a significant level of agreement among the three experts in their ranking of teachers' responses on these topics. In this matrix the teachers were regarded, in pairs, as open-ended, intermediate and expository respectively. Each entry in this matrix, Table 13, consists of the ranks assigned by all three experts to both teachers in each pair.

TABLE 13

Rank order summation matrix for all experts
for each style.

Style	Open-ended	Intermediate	Expository
Teacher Code	H + K	G + J	L + F
1	13	21	29
2	16	29	18
3	11	27	25
4	11	22	30
5	15	25	23
7	16	28	19
8	15	29	21
9	9	27	27
11	22	22	19
Σ	100	230	211

To compare rankings between teaching styles the sign test is used in respect of the nine topics listed in

Table 13. This is considered by Siegel (1956, p.68 et seq) to be an appropriate test since the only assumption underlying its use is that the variable, in this case teachers' verbal style is continuous. The null hypothesis tested in this test is that $p(X_1 > X_2) = p(X_1 < X_2) = \frac{1}{2}$ where X_1 and X_2 are the summation of ranks in respect of a topic for teachers of the styles being compared. Table 14 shows the results for inter-style comparisons.

TABLE 14

Matings assigned to different teaching styles and sign differences.

Topic no.	Open-ended & Intermediate			Open-ended & Expository			Intermediate & Expository		
	OE	I	Dir. of Diff. Sign	OE	Ex.	Dir. of Diff. Sign	I	Ex.	Dir. of Diff. Sign
1	13	21	OE I +	13	29	OE Ex +	21	29	I Ex +
2	16	29	OE I +	16	18	OE Ex +	29	18	I Ex -
3	11	27	OE I +	11	25	OE Ex +	27	25	I Ex -
4	11	22	OE I +	11	30	OE Ex +	22	30	I Ex +
5	15	25	OE I +	15	23	OE Ex +	25	23	I Ex -
7	16	23	OE I +	16	19	OE Ex +	23	19	I Ex -
8	13	29	OE I +	13	21	OE Ex +	29	21	I Ex -
9	9	27	OE I +	9	27	OE Ex +	27	27	I Ex 0
11	22	22	OE I 0	22	19	OE Ex -	22	19	I Ex -
N (No. of matched pairs) = 8 showing differences				N = 9			N = 8		
x (No. of fewer signs) = Nil				x = 1			x = 2		

Reference to a table of probabilities associated with values as small as the observed values of x in the binomial test, Siegel (1956, Table D, p.250) gives these probabilities of occurrence under the null hypothesis.

TABLE 15

Inter-style comparison using the sign test

Comparison of styles	Open-ended & Intermediate	Open-ended & Expository	Intermediate & Expository
No. of pairs showing differences N	8	9	8
No. of fewer signs x	Nil	1	2
Probability p	0.004 [*]	0.020 [*]	0.145 [*]

* One-tailed test.

Table 15 shows that according to the summated rankings of all experts in respect of interview topics about which the Kendall coefficient of concordance indicates that there is significant agreement on rankings, the teachers described as 'open-ended' are significantly less authoritarian in teacher attitudes than are teachers described as 'intermediate' and 'expository' in style. There is no significant difference (at the five per cent level) between physics teachers described as 'intermediate' and those described as 'expository'.

DISCUSSION (2)

Teacher interviews.

As the Kendall coefficients of concordance listed in Table 11 indicate, the experts reached an acceptable measure of agreement about their rankings of teachers on the basis of interview responses to nine of the eleven topics discussed. This suggests that the three experts were judging within the same conceptual structure and employing the same standards. In announcing their decisions two of the judges emphasised that in several instances discrimination was difficult: as one expert stated when giving his rankings for topic number 6; "I put down an order but really this set does not discriminate sufficiently well to allow me to do so. I have no confidence in the result I have given. At another attempt I am sure I would provide another order." Topic number 6 shows a non-significant W in Table 11. The judge's remarks suggest that an attempt to place the teachers' responses on an interval scale might have led to the conclusion that there was little to choose between their attitudes to most topics.

It is surprising to note that one topic which showed poor discrimination between teachers was that which related to their views on the ability of students to tackle experimental work successfully without close guidance from the teacher: it is less surprising to find that teachers were unanimous in their views on student freedom.

The significant W derived from Table 12 indicates that acting as a group the experts attributed ranks to each teacher which were fairly consistently assigned to that teacher on all topics: thus giving an indication of the reliability of the interview schedule as a measuring instrument.

Use of the sign test showed that while teachers identified as open-ended on the basis of classroom observation displayed, in general, less authoritarian attitudes when interviewed than did all the other teachers; the interview rankings failed to confirm the distinction arrived at using the observational technique between teachers whose verbal style was clearly expository and those whose style seemed to be intermediate to the more extreme styles. In fact, as Tables 12 and 13 show, the 'intermediate' teachers tended to exhibit more authoritarian attitudes than did the 'expository' ones.

Table 16 shows a comparison between the teachers ranked (i) according to mean I/D ratio and (ii) according to rank order matrix total for interview topics in Table 12.

It will be seen that for two out of the six teachers the rankings agree perfectly. Nevertheless, the discrepancies in ranking for the remaining four are such that Spearman's rank correlation coefficient $\rho = 0.486$, which is not significant at the five per cent level. It must therefore be concluded that although there is evidence to suggest a link between authoritarian

attitudes and the verbal teaching style of physics teachers, that evidence is inconclusive.

TABLE 16

Comparison between teachers ranked for
(i) I/D ratio and (ii) interview.

Teacher Code		H	K	G	J	F	L
(i)	Rank according to mean I/D ratio	1	2	3	4	5	6
(ii)	Rank according to interview matrix	1	2	5	6	4	3

CHAPTER 6

EVALUATION OF COGNITIVE ATTAINMENT

INTRODUCTION

In chapter 3 the concept of educational objectives was discussed as were the instruments used in the evaluation of their attainment. Since it is a central part of the current investigation to measure educational outcomes, this can be taken to mean that attempts should be made to evaluate the attainment of educational objectives in physics appropriate to the course being followed by the students. As previously stated all students in this study during a period of two years followed the physics syllabus laid down by the Scottish Certificate of Education Examination Board and leading to the award of the Scottish Certificate of Education in physics at the Ordinary grade.

The syllabus and notes covering the Ordinary and Higher grade examinations in physics and published by the Board (1972), sets out what may be regarded as general aims for the guidance of teachers. It states that.... "The general educational aims of this physics syllabus are that pupils should acquire:

- (i) some understanding of man's physical environment and his interactions with it;
- (ii) some of the skills and attitudes required for scientific investigation and communication;
- (iii) an understanding of the applications of physics that enable man to increase his material well-being."

In discussing objectives the Board refers to the work of Bloom et al (1956) and specifies the undernoted hierarchy of cognitive educational objectives which it is stated will be used in devising the examinations in physics at the Ordinary and Higher grades.

Category A Knowledge Recall of useful information, not inert or inoperative ideas.

Category B Comprehension Ability to apply a principle to a situation which it is reasonable to expect most pupils to have encountered in class and where it is obvious to the pupil which principle should be used.

Category C Application Ability to apply a principle to a situation which most pupils would not have encountered in class and where the pupil must first select the appropriate principle.

Category D Highest Abilities This broad category (Bloom 4, 5 and 6) will include:

- (i) the ability to apply principles to problem situations, the solution to which involves two or more stages;
- (ii) the design of an experiment and/or the selection of apparatus of suitable range, type and sensitivity;

- (iii) the critical appraisal of measurements and the interpretation of data;
- (iv) the ability to communicate and provide an explanation or criticism;
- (v) the ability to think creatively to some degree, e.g. in proposing a hypothesis;
- (vi) the ability to solve problems which involve longer calculations requiring a sequence of steps;
- (vii) ability to use data obtained from an experiment, to select an appropriate method of displaying the results, e.g. in graphical form, and to draw conclusions.

It should be noted that all these objectives are expressed in behavioural terms. Houston (1970,p.24) points out that the educational objectives for a physics course should be written in terms of specific abilities in physics, so that they can be unambiguously interpreted by teacher and examiner. In the above list of objectives can be seen the framework of the taxonomy of objectives in the cognitive domain set down by Bloom et al (1956). Category A corresponds to 1.00-Knowledge in the Bloom taxonomy; Categories B and C represent a distinction between application of physics principles in situations which are familiar to the student and these which are not; Bloom's 3.00-Application does not so distinguish between the circumstances in which the application takes

place. Category D, on the other hand, embraces within it all of Bloom's 4.00-Analysis; 5.00-Synthesis; and 6.00-Evaluation, the so-called 'Highest Abilities'. One of the general classes of educational objectives specified in the Bloom taxonomy 2.00-Comprehension, although named in the hierarchy used here, is not described in quite the sense used by Bloom. There it refers to the type of understanding or awareness which allows an individual to use it only in the narrow context in which it is perceived without being able to see its broader implications. In physics, in this stricter sense comprehension means the ability to translate, interpret and extrapolate the facts, principles and theories of physics without necessarily being able to apply them. This matter is discussed at length elsewhere, Houston (1970). It is, of course, possible to construct other hierarchies of educational objectives in physics for a secondary school physics course. The work referred to above contains an alternative structural framework while embracing the same set of skills and abilities set out here.

All the teachers involved in this study were very much aware that the hierarchy of cognitive objectives specified - categories A-B-C-D - above would be taken into account, in the manner later described, by the examiners in constructing the S.C.E. physics examination papers. They could therefore be assumed to have had these objectives in mind throughout their teaching during the period of the investigation. It was thus

considered appropriate to regard those objectives as the criteria for student achievement in the cognitive domain throughout this study; and all attainment tests referred to here had as their purpose the evaluation of student achievement of the objectives stated on p. 146.

MEASURING INSTRUMENTS

1. Objective tests.

Cox (1972) writing about the value of objective examinations points out that when soundly constructed and carefully administered this testing technique can provide a reliable means of assessment which is now being widely used in schools, especially in science.

Three different objective tests were administered to the students on separate occasions as part of the investigation; two of these were compiled by the investigator specially for the purpose - these are referred to hereafter as Attainment Tests I and II; the third being Paper 1 of the Scottish Certificate of Education - Ordinary - grade examination for 1973 - referred to as S.C.E. I. Attainment Tests I and II are shown in full as Appendices IV and V. S.C.E. I is regarded by the Board as confidential and is not available.

Description of objective tests.

Each test consisted of 40 multiple choice five response items (one correct response and four distractors) and lasted for one hour. One mark was awarded for each item correct. A wrong answer incurred no penalty and students were encouraged to attempt all

items. No correction for guessing was applied since when all students respond to all items there is an exact linear relationship between original or 'raw' scores and scores 'corrected' for guessing. Formulae used to correct scores for guessing are based on the assumption that where guessing occurs it takes the form of a random guess from among all the responses provided. Candidates rarely guess in this way but in practice reject one or more responses and guess between the two or more remaining. This matter is fully discussed by Houston (1970), Macintosh and Morrison (1969) and others writing about objective testing procedures.

2. Non-objective tests.

One non-objective test in physics was administered to the students as part of the investigation, it being Paper 2 of the Scottish Certificate of Education - Ordinary - grade examination for 1973, hereafter called S.C.E. II. The question paper for S.C.E. II appears as Appendix VI.

Description of non-objective test.

The test consisted of ten questions of which candidates were required to attempt any five. Each question carried a maximum of ten marks which were allocated according to a marks schedule confidential to the Scottish Certificate of Education Examination Board. One hour and a half was allowed for the paper.

CONSTRUCTION OF MEASURING INSTRUMENTS

1. Objective tests.

(a) Attainment Tests I and II: These tests were compiled from a selection of items specially written for the Test Paper Service conducted by Messrs. Pillans & Wilson Ltd., Edinburgh. The items were devised by a team of physics teachers working under the guidance of this investigator who is also Editor in Physics for the Test Paper Service. The items were constructed to a grid specification of the kind described later. The final selection of items was made by the investigator by having regard to the various criteria described later.

(b) S.C.E. I: Items for the Board's objective test were written by a different team of physics teachers. Although the exact procedure in test assembly is not known, it is known that they worked to a grid specification similar to that used in (a) above and described in detail below.

Two-dimensional grid showing content area and educational objectives

Amongst others, a good objective test must satisfy these two requirements:

- (1) It must have Content Validity; that is it must consist of items which together sample in an adequate way the contents of the syllabus for the course.
- (2) It must have Objective Validity: that is it must include items which among them evaluate all the educational objectives specified for the course.

One way of ensuring that the test satisfies both criteria is to construct it so that it conforms to the grid pattern described in Table 17.

TABLE 17

Content analysis grid for physics objective test.

Objective Validity

Content Validity	Educational objective	A	B	C	D	Total
	Content area					
	Waves					
	Mechanics					
	Heat					
	Electricity					
	Radioactivity					
	Total					

The number of columns corresponds to the number of educational objectives to be evaluated and the number of rows to the number of different content areas in the syllabus. Techniques of test construction using this method are described fully by Houston (1970), Macintosh and Morrison (1969), and other writers. In their notes and syllabus already referred to the Scottish Certificate of Education Examination Board (1972) indicates that an objective-content grid is used in the preparation of the S.C.E. physics objective examination paper.

2. Non-objective test.

S.C.E. II: The non-objective paper used in the investigation was written by a setter appointed by the

Board. In constructing the paper he is advised to have due regard to both content and objective validity. In their 'Conditions and Arrangements 1973' the Board also stipulates that this paper will...."in particular and additionally, assess (in category D):

1. ability to communicate and provide an explanation or criticism
2. ability to think creatively to some degree, e.g. in designing an experiment
3. ability to solve problems involving longer calculations requiring a sequence of steps
4. ability to use data obtained from an experiment or selected from Three-figure Mathematical Tables and Science Data...; to select an appropriate method of displaying results, e.g. in graphical form, and to draw conclusions."

Elsewhere the Board (1972) has stated that to test the achievement of these additional abilities the use of fixed-response items is not appropriate.

VALIDATION OF MEASURING INSTRUMENTS

1. Objective tests.

(a) Attainment Tests I and II: All items used in these tests had previously been pretested and then subjected to item analysis. They were thereafter assembled into a test which was assessed for content and educational objective validity. The details of these validation procedures are given below.

A. Pretest conditions: All items used had been pretested on a sample size of about 150 drawn from the same population of students as those in the current investigation. Under the procedure followed by the Test Paper Service pretests are carried out by the class teachers in schools selected because it is felt that test conditions in these schools will be strictly adhered to. These conditions simulate as closely as possible those under which candidates take the S.C.E. examinations.

B. Criteria used in item analysis: Following the procedures described above a large number of items were available for use in the study. Details were available for each item of (a) its facility value, (b) its discriminatory power and (c) the response pattern of its distractors. Items considered for inclusion in Attainment tests I and II had to fulfil the following conditions in respect of each criterion:

(a) The facility value had to be in the range 0.15-0.90.
(b) The discriminatory power of the item had to be such that the facility value of the top (in the whole test) 33% of pretest candidates had to be greater than that of the middle 33% which in turn had to be greater than that of the bottom 33% of candidates.

(c) At least three of the four incorrect responses had to function to the extent of each attracting not less than 3 per cent of the total pretest candidates. A description of test criteria and full details of item analysis for objective tests are to be found in

Dunn (1967), Hedges (1966), Houston (1970) and Macintosh and Morrison (1969).

C. Content validity: Items finally included in each attainment test were chosen only when it was certain that the topic had been dealt with by that stage in the course. In both tests teachers participating in the experiment were consulted before the test was compiled about topic suitability but not about the suitability of particular items.

D. Educational objective validity: To ensure that the objective category ascribed to each item was as reliable as possible each teacher involved in the study, two Science H.M.I.'s and the author, each working independently, assigned to each item one of the four categories A, B, C or D defined in the syllabus referred to earlier. In each case the judges were instructed to assign to each item the objective category highest in the range A-D which they considered to be appropriate. On the basis of a simple majority decision from these nine subjective judgments a final category of objective was ascribed to each item. The same procedure involving the same judges was used for both attainment tests.

Tables 18 and 19 show the majority objective category attributed to each item for both tests along with the item facility values derived from the pretest data. Also shown for each test is the mean facility value of all items and the total number of items ascribed

to each category of educational objective.

TABLE 18
Facility value and objective category for
items in Attainment Test I.

Item No.	F.V.	Cat.	Item No.	F.V.	Cat.	Item No.	F.V.	Cat.	Item No.	F.V.	Cat.
1	0.90	A	11	0.88	B	21	0.50	A	31	0.32	D
2	0.87	A	12	0.65	B	22	0.86	A	32	0.28	D
3	0.79	A	13	0.35	B	23	0.73	A	33	0.83	B
4	0.71	A	14	0.41	B	24	0.50	A	34	0.60	C
5	0.55	A	15	0.59	B	25	0.51	A	35	0.63	B
6	0.44	A	16	0.86	C	26	0.50	B	36	0.56	D
7	0.80	B	17	0.35	D	27	0.74	A	37	0.51	B
8	0.76	B	18	0.30	D	28	0.90	B	38	0.88	B
9	0.26	A	19	0.72	C	29	0.65	B	39	0.75	B
10	0.56	A	20	0.28	B	30	0.77	A	40	0.55	D
No. of Items Total			A		B		C		D		
in each Cat.			15		16		3		6		
Mean F.V.			(A + B)		0.64		(C + D)		0.50		
0.61											

TABLE 19

Facility value and objective category for items in Attainment Test II

Item No.	F.V.	Cat.	Item No.	F.V.	Cat.	Item No.	F.V.	Cat.	Item No.	F.V.	Cat.
1	0.88	A	11	0.15	C	21	0.50	A	31	0.22	C
2	0.52	A	12	0.63	B	22	0.31	B	32	0.63	B
3	0.36	B	13	0.21	D	23	0.25	D	33	0.17	C
4	0.43	C	14	0.47	C	24	0.32	D	34	0.52	D
5	0.84	B	15	0.55	B	25	0.43	D	35	0.27	C
6	0.33	A	16	0.87	B	26	0.70	D	36	0.27	D
7	0.52	A	17	0.33	C	27	0.60	A	37	0.22	C
8	0.38	A	18	0.45	C	28	0.46	A	38	0.25	D
9	0.46	B	19	0.24	C	29	0.45	A	39	0.44	B
10	0.21	D	20	0.79	A	30	0.35	B	40	0.49	D
No. of Items Total in each Cat. 40			A 10		B 10		C 10		D 10		
Mean F.V. 0.45			(A + B)		0.57		(C + D)		0.33		

In order to estimate the reliability of the judgments and because of the requirements dictated by the general experimental design of this aspect of the investigation (Table 21, p. 164) the item categories shown on Tables 18 and 19 were later dichotomised into (a) items judged to be testing categories A or B and, (b) those judged to be testing categories C or D. Table 20 shows how the original decisions of the nine judges divided between the dichotomised category groups for each item.

Testing the null hypothesis that 'ascription to either category group is random' using the chi-squared test it is found that in Attainment Test I for 24 items ascribed to (A + B) and 4 ascribed to (C + D) $p < 0.17$; and that in Attainment Test II, for 16 items ascribed to (A + B) and 11 ascribed to (C + D), $p < 0.17$. For the remaining items in each test - (12 in A.T.I and 13 in A.T.II) the null hypothesis cannot be rejected.

Since all items were finally ascribed to the dichotomised categories (A + B) or (C + D) according to the judges' majorities shown in Table 20, the objective validity of these items for which the chi-squared test indicated $p > 0.17$ must be suspect.

TABLE 20

Decisions of judges about educational objectives for items.

Attainment Test I						Attainment Test II					
Item No.	No. of Judges		Item No.	No. of Judges		Item No.	No. of Judges		Item No.	No. of Judges	
	A or B	C or D		A or B	C or D		A or B	C or D		A or B	C or D
1	9	0	21	9	0	1	9	0	21	9	0
2	9	0	22	9	0	2	9	0	22	5	4
3	9	0	23	9	0	3	9	0	23	2	7
4	9	0	24	9	0	4	7	2	24	0	9
5	8	1	25	9	0	5	5	6	25	4	5
6	9	0	26	8	1	6	9	0	26	0	7
7	9	0	27	9	0	7	9	0	27	9	0
8	9	0	28	7	2	8	9	0	28	9	0
9	9	0	29	8	1	9	7	2	29	9	0
10	9	0	30	7	2	10	4	5	30	7	4
11	9	0	31	3	6	11	2	7	31	4	5
12	7	2	32	3	6	12	5	4	32	8	1
13	6	3	33	8	1	13	1	8	33	4	5
14	5	4	34	3	6	14	4	6	34	0	9
15	6	3	35	5	4	15	3	6	35	3	6
16	3	6	36	2	7	16	6	2	36	2	7
17	2	7	37	8	1	17	1	8	37	1	8
18	3	6	38	7	2	18	4	5	38	1	8
19	4	5	39	5	4	19	0	9	39	7	2
20	5	4	40	0	9	20	9	0	40	3	6

* denotes items for which χ^2 is not significant at the seventeen per cent level.

(b) S.C.E. 'O' grade 1973 Paper 1 (objective): The Scottish Certificate of Education Examination Board had pretested and carried out item analysis for all items used in this test. The items used were compiled into a test by the Board which in doing so had regard to content validity and educational objective validity according to their normal procedures as briefly outlined below.

A. Pretest conditions: All items used in this test were pretested with a sample size of 350 drawn from a population of Fourth Year students similar to that of which the students in this study are a sample. In their pretest procedure the Board makes use only of schools which present 30 or more candidates for the examinations. (All the schools involved in this investigation normally present more than 30 candidates for 'O' grade physics.) The administration of the Board's pretests is conducted by invigilators specially appointed for this duty and the tests are carried out under conditions more or less identical with those obtaining in the S.C.E. examinations.

B. Criteria for item analysis: All items which were used in the above examination had been subjected to a system of item analysis. The criteria established for item difficulty (referred to before as facility value) and functioning of responses are generally close to these established for the Test Paper Service items. The only difference is in the criterion used to estimate item discrimination. The Board in this respect uses a measure called the Criterion Score which is the mean score for a

candidate on the pretest as a whole. The point biserial correlation is then calculated between a candidate's score on item i (dichotomous) and his Criterion Score. Only items having biserial correlations > 0.30 are accepted.

C. Content validity: The test was compiled by the Board which in doing so selected items which they regarded as reflecting a syllabus balance between topics in physics thus meeting the content specification of the grid referred to in p. 151.

D. Educational objective validity: The method used by the Board in assigning objective categories is unknown as is the procedure used in ensuring that the test had objective validity. The Board does not make public the exact number of items in its objective examinations which are attributed to each of the abilities, A, B, C or D specified. In the case of the 1973 Ordinary grade physics paper the item categories were made available to this investigation on a confidential basis in order that student achievement as measured by this examination could be evaluated.

2. Non-objective test.

S.C.E. 'O' grade 1973 Paper 2 (non-objective): The validation of non-objective examination papers is done by a team of Moderators who work with the Setter in the final stages of preparation, and in doing so are instructed to consider content and objective validity as stated before. This physics paper was not pretested in any way. The marking schedule supplied by the Board

in connection with its marking procedures does not associate questions or part questions with particular abilities or indicate in whole or in part how many marks are awarded for each category of educational objective.

In the analysis of G.C.E. 'O' level science papers into four categories of educational objective, Crossland and Amos (1961) realised the imperfection of such classification and commented on the fact that there would be overlapping between classes. They also emphasised that categorisation of a particular question might be valid for one teaching and learning situation but not for another. Mackaill, (1971) commenting on the multi-functional nature of chemical ability as being represented by different skills and abilities, observes that in the composition of examinations in chemistry.... "...there is no widely based agreement on how to sub-divide into..." these various abilities.

Because of the difficulties of analysing a non-objective paper in terms of educational objectives expressible in a behavioural way no detailed validation of educational objectives was attempted for this paper.

EXPERIMENTAL

General experimental design.

The experimental design for this aspect of the investigation is described below. It constitutes an attempt to measure the attainment by the students of educational objectives in the cognitive domain using the battery of four test instruments (three of them

objective) previously discussed in detail.

These students were in the Third Year of secondary schooling (ages 14-15 years) at the start of the investigation. All were following a course in physics leading to the S.C.E. 'O' grade examination. The criteria specified for the selection of teachers and students have been considered earlier (pp. 89-94) and details of the tests of student attainment used (pp. 149-53). A description of the verbal styles of teaching physics identified in the study was presented (pp. 95-8).

A schematic outline of the research design is shown in Table 21.

TABLE 21

Outline of research design

Student characteristics	Teachers verbal style	Student achievement in cognitive domain
Independent variables	Treatments	Dependent variables
Students' IQ (x)	Open-ended verbal style	Scores in category A+B items (z_1)
Students' social status (y)	Intermediate " "	Scores in category C+D items (z_2)
	Expository " "	Total scores (z_3)

Administration of tests.

1. Attainment Test I: was administered at the end of Third Year by the investigator who acted as invigilator in each case. Students had been warned that the test would take place and that the results would be communicated to the school. It was felt that allowing students to prepare for the test would make for greater uniformity in test conditions for all groups. It was hoped that the decision to make the test results available to the school would increase student motivation. Students took the test under conditions similar to these prevailing at the time of the S.C.E. examination.

2. Attainment Test II: was administered towards the end of Fourth Year and about one month before the students were due to take the S.C.E. examinations. The conditions of administration were identical with these described above for Attainment Test I.

3. S.C.E. I & II: These tests were administered in the schools towards the end of Fourth Year and one month after Attainment Test II. The test conditions were those which normally exist in Scottish schools for the Scottish Certificate of Education examinations. Both physics papers were taken on the same day. Conditions and arrangements concerning these examinations are set out in the Board's annual publication, (1973).

Test results.

Objective tests: All three objective tests were marked to yield the three scores for each student shown in

Tables 22 to 24. These scores were:

- (i) Total score on items designated as testing abilities A + B^{*} z_1
- (ii) Total score on items designated as testing abilities C + D^{*} z_2
- (iii) Total score on all 40 items in a test z_3

* Item designation is on the basis of majorities shown in Table 20.

It follows that for each student; $z_3 = z_1 + z_2$.

Non-objective test: Since this test was not analysed in terms of educational objectives for the reasons stated before (p. 162), only a single total score z_3 was provided in this case for each student.

Testees.

Because of absence and for other reasons some of the students in the study were not present on all four test occasions. In the subsequent analysis reported here all students who completed a particular test were taken account of in the analysis relating to that test. The same students were present for both tests shown in Table 24.

Test results.

Tables 22 to 24 indicate the observed means for student IQ and social status (the independent variables) for the three teaching styles, and also the corresponding means for student scores for items testing abilities A+B; for items testing abilities C+D; and scores for the whole test (the dependent variables).

TABLE 32

Attainment Test I

Initial means-independent and dependent variables for different teaching styles

Teacher style	No. of students	Indep. variables		Dependent variables		
		IQ	Social status*	Cat. A+B	Cat. C+D	Total
Open-ended	39	115.28	4.05	20.49	5.72	26.21
Intermediate	39	112.36	4.35	18.26	4.28	22.54
Expository	29	110.38	4.34	18.38	4.24	22.62
ALL	107	112.89	4.25	19.11	4.79	23.90

(max. 31) (max. 9) (max. 40)

* Indicates social status as measured in terms of father's occupation on the Hall-Jones Scale, in which the lower of two means implies a higher social status.

TABLE 23

Attainment Test II

Initial means-independent and dependent variables for different teaching styles.

Teacher style	No. of students	Indep. Variables		Dependent Variables		
		IQ	Social status \bar{x}	Cat. A+B	Cat. C+D	Total
Open-ended	39	115.59	3.97	12.18	8.10	20.28
Intermediate	35	112.09	4.20	12.23	6.46	18.69
Expository	25	111.80	4.64	11.36	7.44	18.80
All	99	113.39	4.22	11.99	7.35	19.34

(max.20) (max.20) (max.40)

\bar{x} indicates social status as measured in terms of father's occupation on the Hall-Jones Scale, in which the lower of two means implies a higher social status.

S.C.E. I & II

TABLE 24

Initial means-independent and dependent variables for different teaching styles.

Teacher style	No. of students	Indep. Variables		Dependent variables			
		IQ	Social # status	S.C.E. I		S.C.E. II	
				Cat. A+B	Cat. C+D	Total (Paper I)	Total (Paper 2)
Open-ended	34	114.32	3.85	20.50	8.00	28.50	30.44
Intermediate	35	112.34	4.14	20.37	7.46	27.83	26.49
Expository	22	111.45	4.32	18.05	6.77	24.82	23.36
All	91	113.87	4.08	19.86	7.49	27.35	27.21
				(max.28)	(max.12)	(max.40)	(max.50)

indicates social status as measured in terms of father's occupation on the Hall-Jones Scale, in which the lower of two means implies a higher social status.

Inspection of the means for the dependent variables indicates that in all four tests the open-ended style has proved superior in each category and overall. It also suggests that there is little to choose between the other two styles although the intermediate style has yielded a slightly better outcome for the S.C.E. tests shown in Table 24. That these effects may be related to initial differences in the student independent variables is suggested by observing that on all four test occasions the student group taught in the open-ended style is higher in mean IQ and in mean social status rating than both of the other student groups; and that similar but generally smaller differences exist between the means for the other two styles. Because of these differences in background variables it was decided to employ covariance technique (ANCOVA) to adjust student scores in cognitive attainment to take account of inter-style differences in IQ and social status.

Effect of unequal group size.

As Tables 22-24 show the sample sizes for each style were more uneven for the S.C.E. tests than for the attainment tests. As Snedecor and Cochran (1969, pp.277-8) point out, the effect of heterogeneity and non-normality of variance is increased for the F-test with groups of unequal size. For this reason the standard error of the differences between styles was calculated separately using; (1) the pooled sum of squares, and (b) the individual sums of squares in the case where the

variance and group size were most discrepant. The respective standard errors were 1.20 and 1.22 using the procedure described by Snedecor and Cochran. On this basis it was decided to ignore the effect of unequal group size.

Test reliability.

Since the items used in the tests should be considered as random samples of an infinite pool of items that might have been used, it is appropriate to estimate the internal reliability of the objective tests by using an approximation to the Kuder-Richardson Formula 20, see Ary, Jacobs and Razavieh (1972, p.208). This is denoted by the expression $r_{11} = \frac{N\sigma_x^2 - \bar{X}(N-\bar{X})}{\sigma_x^2(N-1)}$ where N is the number of items in the test, σ_x^2 is the variance of the test scores, \bar{X} is the mean test score and r_{11} the reliability coefficient of the whole test. As the Kuder-Richardson formula gives a reliability which is equivalent to the mean of all possible split-half reliability estimates it will tend to be lower where the test, as in the present instance, is designed to measure more than one ability. For this reason a (K-R 20) reliability coefficient was calculated for each of the scores z_1 , z_2 and z_3 for each of the objective tests. The details are shown in Table 25.

TABLE 25

Kuder-Richardson-formula 20 - reliability coefficients for objective tests.

Test	Score	N	\bar{X}	σ^2	r^2
Attainment Test I	Cat. A+B (z_1)	31	19.11	17.13	0.59
-do-	Cat. C+D (z_2)	9	4.79	3.77	0.46
-do-	Total (z_3)	40	23.90	20.28	0.67
Attainment Test II	Cat.A+B (z_1)	20	11.99	7.81	0.41
-do-	Cat.C+D (z_2)	20	7.35	7.66	0.41
-do-	Total (z_3)	40	19.34	23.26	0.56
S.C.E. I	Cat. A+B (z_1)	28	19.86	19.90	0.74
-do-	Cat. C+D (z_2)	12	7.49	5.30	0.51
-do-	Total (z_3)	40	27.35	37.99	0.79

In interpreting these figures it must be borne in mind that the reliability of a test is a function of the number of items in the test as well as of the heterogeneity of the scores.

Inspection of the data in Table 25 shows that the tests or parts of a test which have a low reliability coefficient are these for which the number of items is small, as in the case of z_2 for ATI and SCE I: or where the variance is small in relation to the maximum possible score as in Attainment Test II. The students' performance in both parts of Attainment Test II and in the whole test was poorer than in the other two tests.

Homogeneity of background variables.

Although it is virtually impossible to take account of all possible teacher, student and environmental variables it was considered essential to control for such dominant factors as (a) student IQ and (b) social status of students. These data were obtained for all students in the experiment during the period of preliminary investigation using the procedures outlined in chapter 4. All students' scores in the tests of cognitive attainment were then adjusted to take account of inter-style differences in these vital background variables.

Adjustment of attainment scores for differences in independent variables.

Analysis of covariance is used to adjust the dependent variables z_1 , z_2 and z_3 to take account of inter-style differences in the student independent

variables x and y . The best 'weighted' composite of both independent variables is used in the analysis. The statistical procedure is described in detail in Appendix VII.

The style means of z_1 are adjusted to take account of the initial differences in x and y in the case of Attainment Test I; an identical procedure is used to adjust the style means of z_2 and z_3 in the same test, and to adjust all three dependent variable means of the scores in Attainment Test II and SCE I. Although there is only one outcome variable z_3 for SCE II the same procedure is also used to adjust the style means of z_3 in respect of that test.

Table 26 shows the final adjusted analysis of z_1 for Attainment Test I in which the sums of squares used have been adjusted in the manner described in Appendix VII.

TABLE 26

Adjusted analysis of marks in category A+B items in Attainment Test I after allowing for differences in students' IQ and social status rating (optimally weighted)

Source	d.f.	Sums of Squares	Mean Square	F
Styles	2	51.2260	25.6130	$\approx 1.932 (2,102)$
Students	102	1352.0925	13.2558	(not sig. at 5 per cent)
Total	104	1403.3185	-	-

$$\approx F_{0.05} = 3.08$$

The non-significant F in Table 26 indicating no significant differences at the five per cent level among the mean scores of students taught in different styles when these means are adjusted for inter-style differences in student IQ and social status shows that it is unnecessary to test the significance of differences between individual style means. The procedure indicated in paragraph 7 of Appendix VII is invoked only in cases where the analysis of covariance yields a significant 'F'.

On the other hand, the procedure described in paragraph 6 of that appendix is used to obtain the adjusted attainment means for all styles and tests. Tables 27 to 30 show these adjusted means for each of the four tests. The F at the foot of each column of these tables indicates whether after adjusted for differences in IQ and social status there still remain significant inter-style differences among the attainment means.

TABLE 27

Attainment Test I - Attainment means after adjustment for IQ and social status difference

Teacher style	n	Categories A + B	Categories C + D	Total +
Open-ended	39	19.973	5.513	25.462
Intermediate	39	18.392	4.334	22.732
Expository	29	18.887	4.447	23.359
Total	107	-	-	-
F:	-	1.932	5.495 [±]	4.530 [±]

(d.f. 2,102)

F_{0.05} = 3.09

TABLE 28

Attainment Test II - Attainment means after adjustment for IQ and social status difference.

Teacher style	n	Categories A+B	Categories C+D	Total +
Open-ended	39	11.978	7.856	19.834
Intermediate	35	12.337	6.577	18.914
Expository	35	11.521	7.657	19.178
Total	99	-	-	-
F:	-	0.661	2.515	0.384

(d.f. 2,94)

$F_{0.05} = 3.09.$

TABLE 29

S.C.R. I - Attainment means after adjustment for IQ and social status difference.

Teacher style	n	Categories A+B	Categories C+D	Total +
Open-ended	34	20.120	7.798	27.917
Intermediate	35	20.303	7.525	28.028
Expository	22	18.424	6.977	25.401
Total	91	-	-	-
F:	-	1.829	1.143	1.915

(d.f. 2,86)

$F_{0.05} = 3.10$

+ indicates in Tables 27 to 29 that because each of the three columns of means has been independently adjusted, entries in the 'Total' columns are not the exact sums of the corresponding entries in the other two columns.

TABLE 30

SOE II - Attainment means after adjustment for IQ and social status difference.

Teacher style	n	Total
Open-ended	34	29.861
Intermediate	35	26.670
Expository	22	23.920
Total	91	-
F:	-	4.417*

(d.f. 2,86)

$F_{0.05} = 3.10$

* Significant beyond the 5 per cent level.

In the cases - Tables 27 and 30 - where 'F' indicates that there still remain inter-style differences in attainment significant beyond five per cent, the modified 't' test, equation (13) in Appendix VII is used to test the significance of these differences. The values of 't' and their significances in these instances are shown below in Table 31.

TABLE 31

Analysis of differences among individual adjusted means within columns for Attainment Test I, (Categories C+D and Total) and SCE II.

Test	Attainment Test I		SCE II	
	Attainment Variable	Categories C+D	Total	Total
Open-ended	(1)	$t_{12}=3.05^*$ (df 76)	$t_{12}=2.64^*$ (df 76)	$t_{12}=1.70^*$ (df 67)
Intermediate	(2)	$t_{23}=0.27$ (df 66)	$t_{13}=1.86^*$ (df 66)	$t_{13}=2.76^*$ (df 54)
Expository	(3)		$t_{23}=0.57$ (df 66)	$t_{23}=1.30$ (df 55)

* denotes 't' significant at beyond 5 per cent. (one-tailed test)

The values of 't' shown in Table 31 may be interpreted as follows:

- (i) In Attainment Test I the students taught in an open-ended style obtained a higher mean score (significant beyond 5 per cent) than did students taught in the other two styles both in respect of the items adjudged to be testing the highest abilities (categories C+D) and on the test as a whole.
- (ii) In SCE II, the only non-objective test in the battery, the students taught in the style described here as open-ended again obtained a mean score in the test overall which was significantly higher - beyond 5 per cent - than were the mean scores of students taught in the other styles.

There are no other significant inter-style differences in these tests and none at all in Attainment Test II and SCE I.

Inter-test correlation.

Product-moment correlation coefficients were calculated:

- (a) between the total scores in each of the four tests for each teaching style and overall, and
- (b) between the scores in the items testing abilities A+B and C+D in each of the three objective tests for each teaching style and overall.

The correlations for each style are shown, grouped to allow comparison among styles in Tables 32 - 34. The decimal points in these tables are omitted for convenience. All correlations are positive.

TABLE 32

Correlation coefficients between students' total scores in attainment tests.

Style	Open-ended				Intermediate				Expository			
Test	ATI	ATII	SCETI	SCETI	ATI	ATII	SCETI	SCETI	ATI	ATII	SCETI	SCETI
A.T. I	-	568	575	355	-	759	733	592	-	629	533	454
A.T. II		-	553	323		-	706	630		-	807	829
SCET I			-	682			-	810			-	881
SCET II				-				-				-
Σ	-	568	1128	1360	-	759	1439	2032	-	629	1340	2164
$\Sigma \Sigma$				3056				4230				4133

TABLE 33

Correlation coefficients between students' scores in items testing categories A+B in objective attainment tests.

Style	Open-ended			Intermediate			Expository		
Test	ATI	ATII	SCET	ATI	ATII	SCET	ATI	ATII	SCET
A.T. I	-	462	502	-	611	650	-	655	543
A.T. II		-	526		-	553		-	805
SCET I			-			-			-
Σ	-	462	1028	-	611	1203	-	655	1348
$\Sigma \Sigma$			1490			1814			2003

TABLE 34

Correlation coefficients between students' scores in items testing categories G+D in objective attainment tests.

Style	Open-ended			Intermediate			Expository		
Test	ATI	ATII	SCEI	ATI	ATII	SCEI	ATI	ATII	SCEI
A.T. I	-	422	381	-	730	749	-	336	173
A.T. II		-	425		-	632		-	670
SCE I			-			-			-
Σ	-	422	806	-	730	1381	-	336	843
$\Sigma \Sigma$			1228			2111			1179

From Tables 32-34 it is seen that the mean correlation coefficient is generally lower for the open-ended style than for the other two. How this may be construed is discussed later on.

Table 35 shows the inter-correlations between scores on categories A+B items, categories C+D items and total over all three teaching styles for all the tests.

TABLE 35
Correlation coefficients between students' scores in attainment tests irrespective of teaching style.

Dependent variable	Total score (z3)			Score in cat. C+D (z2)		Score in cat. A+B (z1)	
Test	ATI	ATII	SCEI	SCHEI	ATI	ATII	SCEI
Attainment Test I	-	672	653	533	-	562	532
Attainment Test II		-	672	580		-	564
SCE I			-	789			-
SCE II				-			-
Σ	-	672	1325	1892	-	562	1096
$\Sigma \Sigma$			1997	3889			1658
						-	550
							1199
							1749

DISCUSSION OF RESULTS.

The initial means of the dependent variables, that is the means of the scores in the attainment tests - Tables 22 - 24 - although generally favourable to the students taught in the open-ended style show mostly small differences of one or two points of score. Apart from the possibility that such differences may be related to other controlled independent student variables, there must exist doubts about the generality of such results based on a small sample of test items; in some cases on only 9 or 12 items. This raises the question of test reliability and Table 25 shows that in respect of these measures already referred to, the Kuder-Richardson reliability coefficients were 0.46 and 0.51 respectively. It is often stated, for example, by Ary, Jacobs and Razavieh (1972, p.209) that test reliability coefficients should not be below 0.70. On the other hand since the Kuder-Richardson estimate emphasises the equivalence of all items in the test; r_{11} the reliability coefficient, would be reduced where that test, as in this investigation, purports at least to measure several different abilities. The reliability coefficients shown on Table 25 for items in tests which are intended to be fairly homogeneous in the abilities they are designed to measure are rather disappointing, especially in the case of Attainment Test II since each part of that test contained 20 items. The students overall found Attainment Test II extremely difficult;

for all students a mean score of 19.34 out of 40 was recorded, compared with 23.90 for Attainment Test I and 27.35 in the case of the S.C.E. Objective paper. It is difficult to find a reason for the low achievement realised on that occasion other than to point to the high loading of items (50%) testing the higher abilities. On all three objective tests the students' performance was superior on the items testing abilities A and B. Table 36 shows a comparison of the mean scores per item for each part of the three objective tests.

TABLE 36
Mean score per item for objective tests.

Test	A.T. I	A.T.II	SCE I
Mean score per item on A or B cat.	0.62	0.60	0.71
Mean score per item on C or D cat.	0.53	0.37	0.62
Mean score per item on all items	0.59	0.48	0.68

Since the mean score per item is the same as the mean facility value for all items being considered it is appropriate to compare the data above with the pretest data for Attainment Tests I and II shown at the foot of Tables 18 and 19. This comparison shows that the predicted test difficulty was confirmed by the performance of students in the study.

When the substantial level of disagreement among

judges about the ability category assigned to items is taken into account there must be some doubt about the meaning of the significantly better performance in the nine categories C and D items in Attainment Test I, of students taught in the style described here as open-ended. Although indicated in Table 27 as significant beyond the 5 per cent level, the difference is just over one point of score; and this on a sample of only nine items comprising a sub-test of low internal reliability and dubious validity. The evidence may be thought to be less than sufficient to advance the claim that an open-ended teaching style leads to greater attainment of C and D abilities in physics. In an interim report on this investigation Houston and Pilliner (1974) pointed out this fact and emphasised the need for further evidence of the superiority of the open-ended method.

The other significant results recorded in the assessment of cognitive attainment and noted also in Table 27 and in Table 30 are more soundly based. As Table 30 shows the students taught in the open-ended style performed better overall in the non-objective SCE Paper 2 than did students taught in the other styles, even after account had been taken of initial differences in IQ and social status. It could be argued that the results of open-ended teaching are more likely to be manifested in a test situation where for example... 'the ability to think creatively'... is being tested,

as in SCE II, than in the fixed response format of the other three tests. Students who have been encouraged to write their own experimental reports may be at an advantage in dealing with questions designed to test the 'ability to communicate and provide an explanation or criticism', another aim of SCE II.

It is more difficult to explain why the superiority in the test as a whole of the open-ended style in Attainment Test I is not repeated in either of the other two objective tests. One possible reason may be that while Attainment Test I was taken at the end of Third Year the other two objective tests were taken respectively 9 and 11 months later. Again the inter-test correlations shown on Tables 32 - 34 may provide a clue. It is striking that the inter-correlations between test scores for students taught in the open-ended style are markedly lower than the correlations between the scores for the other students indicating that perhaps an open-ended style of teaching physics leads to more erratic student performance from one test occasion to the next than do the other styles. Table 33 indicates that in items testing recall and the more routine skills in physics, the expository style seems to achieve more consistent but not better results. This appears to be a plausible result if we assume that an expository teacher will drill his students in the recall of facts in physics and in the straightforward application of physics principles. In fact, one general conclusion that might be drawn from

the results of this part of the investigation is that while overall the response of students to an expository style of teaching physics is not superior to the response of similar students to other styles, the expository teacher is more likely to find that his students respond consistently; only in the case of the C and D items - Table 34 - do the students of the open-ended teachers appear to be more consistent than the students taught by the expository teachers.

Table 35 shows that, as expected, when teaching style is disregarded the students tend to be more consistent in the measures associated with educational objectives lower in the hierarchy of objectives than with those which test the higher objectives.

There would seem to be insufficient evidence to justify a firm conclusion that one teaching style has been shown to be better than another. However, the evidence, though tentative and in places contradictory, does suggest that the open-ended style is more successful than the expository style in achieving the more complex cognitive objectives. In no single instance did the students taught in the expository style show a higher adjusted mean score in any of the outcome variables than did those taught in the open-ended manner.

EVALUATION OF ATTITUDE DEVELOPMENT

INTRODUCTION

In Chapter 3 is discussed the work of Bloom (1956), Krathwohl, Bloom and Masia (1964) and others on the development of educational objectives associated with attitudes; that is with human reactions or responses to the subject content of education. The evaluation of these educational developments in the affective domain is considered. The recent emphasis in science education has shifted from a primary concern with knowledge of science to a greater regard for the importance of the social and economic implications of science. Curriculum Paper 7 published by the Scottish Education Department (1969) specifies educational objectives in the affective domain as being important in science courses for non-certificate students in Third and Fourth Years in Scottish schools. It is therefore considered essential in the present study to attempt to evaluate the effect, if any, of different verbal teaching styles on student attitudes towards physics. It seems reasonable to hypothesise that when all students follow the same curriculum, any differential change of attitudes concerning physics must be due, at least in part, to the teaching mode.

However, unlike the situation in the cognitive area described in the previous chapter there is no hierarchy of educational objectives in the affective domain specified for the Scottish physics syllabus followed by the students with whom this study is concerned.

Consequently it may be that teachers in general are less likely to see the development of favourable attitudes to physics as one of their aims in teaching their subject.

The objectives referred to in Curriculum Paper 7 are used as a starting point from which to develop a list of educational objectives specific to the study. These eight objectives, altered only by substituting the word 'physics' for 'science', are:

1. Awareness of the relationship of physics to other disciplines of knowledge.
2. Awareness of the importance of physics in the working, leisure and social aspects of the community and science in general.
3. An interest and a willingness to participate in physics - based leisure pursuits.
4. Willingness to conform to and take an interest in propagating sensible rules for safety and good health for the sake of the community, as well as of the individual.
5. An interest in and a willingness to participate in conservation of the natural environment.
6. An interest in gathering information about physics through all the media of communication.
7. An appreciation of man's responsibility to use physics for the benefit of society.
8. An attitude of objectivity to all decisions and assessments required of the individual.

Comparison of these objectives with the taxonomy of

educational objectives in the affective domain specified by Krathwohl, Bloom and Masia (1964) shows that (1) and (2) above would be classified in the general taxonomy as 1.0 (Receiving); 3, 4, 5 and 6 as category 2.0 (Responding); with 7 and 8 meriting classification in 3.0 (Valuing), or even 4.0 (Organisation). These general classes are described in some detail in chapter 3. The terms 'awareness', 'interest', 'willingness', 'appreciation' and 'attitude' are key-words in the description of the aforementioned and of most other taxonomies of affective domain objectives.

It is doubtful whether the objectives detailed above are more readily developed by one teaching style than by another. It is difficult to believe, for example, that achievement of objective 4 (p. 190) is likely to depend on the teacher's verbal style. Perhaps the most effective way in which a physics teacher can develop in his students a sensible attitude towards health and safety is by his own behaviour. The physics teacher's approach to safety in the laboratory may be revealed when he is teaching radioactivity. Would an expository teacher be more likely than an open-ended one to be careful in his own dealings with radioactive materials; and hence a better exemplar in his teaching of the safe use of such materials? Or would the converse be true? Again, whatever his style, a physics teacher who is a radio club enthusiast might be effective in encouraging his students' interest in a physics-based leisure pursuit.

The association between some affective objectives and teaching style appears tenuous.

These difficulties were realised at the outset of the study. It was nevertheless decided to draw up a list of affective objectives which might be influenced by different teaching styles. It was anticipated that further insight would be gained into these difficulties during validation of the instruments used to evaluate the attainment of these objectives. A new list of six educational objectives in the affective domain was developed consisting of five of the objectives previously specified together with a new one. Three of the original eight were rejected either because their development seemed to be only indirectly related to physics teaching or because it was considered that the current physics syllabus was unlikely to nourish their development. This revised list of objectives - not in any hierarchical order - is given below.

1. Awareness of relationship of physics to other disciplines of knowledge.
2. Awareness of the importance of physics in the working, leisure and social aspects of the community and society in general.
3. An interest and a willingness to participate in physics-related leisure pursuits.
4. An interest in gathering information about physics through all the media of communication.
5. An attitude of objectivity to all decisions and assessments required of the individual.

* 6. An enthusiasm for physics as an attractive and satisfying intellectual discipline.

* Additional objective, not originally specified.

These, then, were the six educational objectives to be evaluated in this part of the investigation.

MEASURING INSTRUMENT

Earlier in this report (p. 70) reference is made to several kinds of test instrument suitable for the evaluation of objectives in the affective domain. It was decided to use the questionnaire method in this part of the study. The use of student interviews was rejected because (i) it would have been difficult to find time to interview a suitable cross-section of the students, (ii) it would have been difficult to associate interview data with separate objectives, (iii) to conform to the experimental design, the same students would have had to be interviewed again.

Description of questionnaire.

The final form of the questionnaire consists of 38 statements to each of which students are invited to express agreement or disagreement on a five point scale described by Likert (1932). Each of these statements is linked to one of the six educational objectives derived from the Scottish Education Department (1969) guide lines. It was hypothesised that these objectives might be influenced by the verbal style of the physics teacher.

The final version of the questionnaire is reproduced as Appendix IX. The procedure for producing a Likert scale, called by Bird (1940) the method of summated ratings is fully described by Oppenheim (1966). Likert scales are reputedly unidimensional, so that the reliability of such scales should be high. The reliability of the scales used here is considered later (p. 203).

The Likert five-point scale is a compromise. A more sensitive technique would employ more than five points but would perhaps require too fine a judgment on the part of the respondent. By contrast, a straightforward agree-disagree situation might not allow him adequate freedom of expression. Where a Likert scale is used to record attitudes, an equal interval property cannot be assumed, however the questionnaire is scored. The range of ratings used here is: Strongly agree-Agree-Uncertain-Disagree-Strongly disagree. A response 'Strongly agree' does not necessarily express agreement twice as strong as a response 'Agree' to the same statement. The effect of this restriction on the analysis of data resulting from the use of the questionnaire is discussed later.

Scoring.

The five ratings are scored 4-3-2-1-0 or 0-1-2-3-4 for each statement depending on whether a statement is favourable or not to the attitude it is intended to measure. Edwards (1957) in discussing the method of summated ratings shows that this marking system corresponds closely to the

normal deviate weights except that extreme responses are over-weighted. Since each statement is associated with a particular attitude, a student's score for that attitude is the straight sum of his ratings on all statements connected with it. The scoring system described implies that a high score represents a favourable attitude regardless of whether statements are themselves favourable or unfavourable.

Construction of measuring instrument.

A pilot version of the questionnaire containing 50 statements was prepared from a list of statements which had been discussed with colleagues. In each section of the questionnaire half of these statements were favourable to the attitudes associated with them and half were unfavourable, so that the greater weights accorded to the 'Strongly agree' ratings in favourable statements would be balanced by the greater weights accorded to the 'Strongly disagree' ratings in unfavourable statements. Each of these 50 statements formed part of a Likert scale designed to measure development in one of the six attitudinal educational objectives referred to earlier. Many of the 50 statements used in the pilot questionnaire were based on statements devised and used by Brown and Davis (1973)* to study attitudes of students in First and Second Years (12-14 year olds) towards the Scottish Integrated Science course. Some of these statements were modified to make them more appropriate to this investigation.

* The author is deeply indebted to Sally Brown of the University of Stirling for permitting the use in the present investigation of test materials designed by her.

Additional statements considered relevant to the attitude scales proposed were added after discussion with colleagues.

Validation of measuring instrument.

The validity of the scales at this stage rests on the subjective judgment of the experimenter and his advisers. They decided which statements were appropriate to the six scales designed to assess the attainment of each educational objective under discussion. Table 37 shows the statements in the pilot version - (shown in full as Appendix VIII) - attributed to each objective.

TABLE 37

Pilot questionnaire statements and their related objectives.

Objective No. 1										9 statements									
Statement No.	3	6	11	16	21	26	31	36	46	Direction	A	A	D	A	D	D	D		
	A	A	D	A	A	D	A	D											
Objective No. 2										11 statements									
Statement No.	4	8	13	17	22	27	32	37	41	42	47	Direction	D	D	D	A	A	D	A
	D	D	D	A	D	D	D	A	D	A									
Objective No. 3										5 statements									
Statement No.	5	15	25	35	50	Direction	A	D	A	D		Direction	A	D	A	D			
	A	D	A	A	D														
Objective No. 4										5 statements									
Statement No.	10	20	30	40	45	Direction	D	D	A	D		Direction	D	D	A	D			
	D	D	D	A	D														
Objective No. 5										10 statements									
Statement No.	1	7	13	18	23	28	33	38	43	48	Direction	A	D	D	A	D	A	A	
	A	D	D	D	A	A	D	D	A										
Objective No. 6										10 statements									
Statement No.	8	9	14	19	24	29	34	39	44	49	Direction	A	D	A	D	D	A	A	
	A	D	A	D	D	A	D	D	A										

The 'direction' refers to whether the statement is favourable to the objective or not; A denotes 'agree', i.e. a favourable statement and D " 'disagree', an unfavourable statement.

Each of these objectives is specified in full (p. 198). It will be observed that the scales consist of unequal numbers of statements. Objectives 3 and 4, for example, are each measured in the pre-test on a scale constructed on the basis of student responses to only five statements. Oppenheim (1966) states that although arbitrary the number of statements used in a Likert scale may be quite small. Hall (1934) reports Likert scales of 7 statements giving reliability coefficients from 0.77 to 0.87 and one of five statements giving coefficients from 0.69 to 0.84.

Pre-testing Procedure.

This 50-statement questionnaire was pretested before being used in the investigation proper. It was administered in two schools to 84 students at the beginning of their Third Year. Although outwith the study, these students are regarded as forming a sample drawn from the same population as that from which the sample of students concerned in the investigation is drawn. The pre-test was carried out under the same conditions as those which obtained in the subsequent use of the questionnaire and which are described later for the experiment.

Analysis of pre-test data.

A. Intercorrelations between scores on different objectives.

The pre-test yields for each student a score on each of the six scales referred to in Table 37. The product-moment correlation coefficients among these scores are indicated on Table 38.

TABLE 38

Intercorrelations between pre-test scores
on different scales.

Objective	1	2	3	4	5	6
1	-	0.69	0.55	0.51	0.26	0.46
2		-	0.58	0.43	0.23	0.49
3			-	0.62	0.28	0.60
4				-	0.26	0.74
5					-	0.15
6						-
Σ	2.47	2.42	2.63	2.56	1.18	2.44

All correlations are positive.

On consideration of these results it was decided to reduce the original six objectives to three by; (a) combining objectives 1 and 2; (b) combining objectives 3, 4 and 6; and (c) keeping objective 5 by itself.

Comparison of objectives 1 and 2 shows that both are associated with an awareness of the significance of physics, whilst objectives 3, 4 and 6 relate to interest in and enthusiasm for physics. Objective 5 does not sit easily with either of these groups so that as expected students' scores in the scale associated with that objective correlate poorly with their scores in the other five scales.

These considerations lead to the formulation of three new combined objectives, hereafter referred to as Attitudes I, II and III. Each is specified below:

Attitude I. Awareness of the significance of physics in everyday life.

(Objectives 1 and 2)

Attitude II. An attitude of objectivity learned from physics.

(Objective 5)

Attitude III. An interest in and an enthusiasm for physics.

(Objectives 3, 4 and 6).

The subsequent item analysis was carried out in relation to these new attitude scales.

B. Item analysis.

The selection of items (or statements) for inclusion or rejection in the final version of the questionnaire should depend on some form of item analysis where the scales are constructed using the method of summated ratings. This is done for each scale, three in this case, by considering the frequency distribution of scores on all statements comprising each scale.

In this study, student's 't' is used in the manner described by Edwards (1957, pp.152-5) to compare mean scores between criterion groups defined as: (a) the 25% of the students with the highest total scores on all statements related to a specific attitude, and (b) the 25% of the students with the lowest total on all statements related to the same attitude.

The value of 't' thus obtained is a measure of how well that statement discriminates between students with a

highly favourable attitude and those with a highly unfavourable attitude as indicated by the other statements making up that particular attitude scale. For example for Statement Number 43, the respective means of the high and low scoring groups were:

$$\bar{X}_H = 2.86 \quad \bar{X}_L = 1.76 \quad (n = 21 \text{ for each group})$$

$$t = 4.10 \quad (\text{d.f. } 40)$$

$$(t_{0.05} = 1.68, \text{ one-tailed test}).$$

This result may be interpreted as indicating that the mean response of the favourable and unfavourable groups towards Statement No. 43 differs significantly at less than five per cent. Thus the statement discriminates in the same way as the other statements forming the Likert scale for Attitude II.

Table 39 shows the values of 't' obtained in the item analysis of the pre-test statements for the three attitudes.

TABLE 39

Item analysis for all statements in attitude questionnaire.

Attitude I		11 Items																					
Statement t	3	4	5	6	8	11	12	16	17	21	22	26	27	31	32	36	37	41	42	46	47		
	2.1	1.5	5.3	6.8	2.8	3.1	2.6	1.5	1.3	0.5	2.0	2.6	5.4	0.9	2.4	1.5	6.1	1.7	2.0	3.9	0.8		
	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Attitude II		10 Items																					
Statement t	1	7	13	18	23	28	33	38	43	48													
	4.0	3.9	4.2	3.8	4.8	5.2	4.3	5.1	4.1	3.2													
	x	x	x	x	x	x	x	x	x	x													
Attitude III		17 Items																					
Statement t	2	9	10	14	15	19	20	24	25	29	30	34	35	39	40	44	45	49	50				
	6.3	6.3	2.1	11.9	7.3	7.3	11.8	6.3	1.6	6.3	1.3	9.2	2.9	9.7	5.4	6.5	9.5	11.1	2.3				
	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				

x denotes statements selected for use in the final version of the questionnaire. All those used have 't' significant for p 0.05.

Scale reliability.

As Table 39 indicates, the questionnaire used in the investigation contains three Likert scales. The internal consistency reliability of each scale was estimated using the boosted split half procedure. Table 40 shows the split-half and Spearman-Brown reliability coefficients for the three Likert scales employed in the experiment.

TABLE 40

Split-half and Spearman-Brown reliability coefficients for each Likert scale, using pretest data.

				All Statements	
Attitude	No. of Statements	Split-half r_{12}	Spearman-Brown r_{12}^1	Mean Score	Variance
I	11	0.6937	0.8192	26.55	47.89
II	10	0.4535	0.6240	27.78	19.39
III	17	0.8018	0.8900	37.07	170.77

The low reliability of the scale for Attitude II estimated from the pretest data may be connected with the small variance for student scores on that scale throughout the investigation - see Table 46 (p. 209).

Table 41 shows how the 38 statements in the final form of the questionnaire - Appendix IX - are divided among the three attitudes, and indicates which are regarded as favourable and which as unfavourable statements.

TABLE 41

Finalised questionnaire statements and their related attitudes.

Attitude I		11 statements																
Statement No.	Direction	3	5	7	9	11	13	15	19	21	24	28	35					
		A	A	A	D	D	D	D	D	A	A	D						
Attitude II		10 statements																
Statement No.	Direction	1	6	12	15	18	22	26	30	33	37							
		A	D	D	D	A	A	D	D	A	A							
Attitude III		17 statements																
Statement No.	Direction	2	4	8	10	14	16	17	20	23	25	27	29	31	32	34	36	38
		A	D	D	A	D	D	A	D	A	D	A	D	A	A	A	D	

The 'direction' refers to whether the statement is favourable or unfavourable to the attitude: 'A' denotes agree, a favourable statement; 'D' denotes 'disagree', an unfavourable statement. Here the statement number is its number in the final version of the questionnaire, Appendix IX.

EXPERIMENTAL

General experimental design.

In this part of the investigation an attempt is made to find whether changes in student attitudes towards physics during the two year period of the main investigation can be attributed to the effect of different verbal teaching styles. The same attitude questionnaire, previously described, is administered on different occasions to all students in the study.

A schematic outline of the design of the research is shown in Table 42.

TABLE 42

Schematic outline of research design.

Student characteristics		Teacher's verbal style	Student scores in questionnaire	
Independent variables		Treatments	Dependent variables	
Students' IQ	(x)	Open-ended verbal style	Scores on Likert scale - Attitude I	+
Students' social status	(y)	Intermediate verbal style	Scores on Likert scale - Attitude II	+
		Expository verbal style	Scores on Likert scale - Attitude III	+

+ The questionnaire was administered three times so that each student obtained three scores on each attitude scale.

Administration of questionnaire.

The same attitude questionnaire was administered at the beginning of the students' Third Year, before they had been taught any physics as such; at the start of their Fourth Year, one year later; and two months before the

SCE 'O' grade examinations. Because the intervals between the occasions were 12 months and 7 months respectively the effect of pretest on post-test was regarded as minimal. On all occasions the investigator acted as invigilator. In addition to the guidance given on the rubric of the questionnaire, students were exhorted to respond in a spontaneous way to each statement; and were told that no information whatsoever concerning their responses would be communicated to anyone connected with the school. It was hoped that this guarantee of confidentiality would encourage a sincere response.

Testees.

As in the case of the tests of attainment in the cognitive domain some students in the study did not respond to the questionnaire on all three occasions. The analysis subsequently shown here refers only to those who were present and completed all three.

Results.

The questionnaire was scored in the same way on each occasion so that attitude changes could be detected. Each student had a total score for each attitude scale each time he responded to the questionnaire, nine scores in all as shown in Table 43.

TABLE 43

Student scores on attitude questionnaire.

Attitude	Max. Score	Test Occasion		
		First	Second	Third
I	44	z_1	z_2	z_3
II	40	z_1	z_2	z_3
III	68	z_1	z_2	z_3

The means \bar{z}_1 , \bar{z}_2 and \bar{z}_3 of these scores are shown for each attitude separately on Table 45.

Using the student scores indicated in Table 43 above, it is possible to measure shifts in attitude between administrations of the questionnaire. The attitude shifts are shown in Table 44.

TABLE 44

Attitude shifts measured from scores in questionnaire.

Period	Stage	Attitude shift for each attitude
First year of investigation	Third Year	$z_2 - z_1$
Second year of investigation	Fourth Year	$z_3 - z_2$
Full period of investigation	Third & Fourth Years	$z_3 - z_1$

Table 45 shows the mean scores on the questionnaire \bar{z}_1 (first occasion) \bar{z}_2 (second occasion) and \bar{z}_3 (third occasion) for different teaching styles and all three attitudes. It shows also the corresponding mean differences $\bar{z}_2 - \bar{z}_1$; $\bar{z}_3 - \bar{z}_2$; and $\bar{z}_3 - \bar{z}_1$, which are taken to represent approximately the attitude shifts during the Third Year; during the Fourth Year; and over the two year period.

TABLE 45

Means and mean differences of student scores in attitude questionnaire.

\bar{x}_1 is score on first occasion; \bar{x}_2 on second occasion one year later; and \bar{x}_3 the score on third occasion seven months after the second occasion.

Teacher style	n	\bar{x}_1	\bar{x}_2	$\bar{x}_2 - \bar{x}_1$	\bar{x}_3	$\bar{x}_3 - \bar{x}_2$	$\bar{x}_3 - \bar{x}_1$
<u>Attitude I: Awareness of significance of physics in everyday life.</u>							
Open-ended	35	33.26	30.57	-1.69	30.37	-0.20	-1.89
Intermediate	32	29.69	30.06	+0.37	30.91	+0.85	+1.22
Expository	23	29.13	27.15	-2.00	27.61	+0.48	-1.52
<u>Attitude II: Objectivity learned from physics.</u>							
Open-ended	35	27.71	30.00	+2.29	30.06	+0.06	+2.35
Intermediate	32	26.53	28.69	+2.16	29.19	+0.50	+2.66
Expository	23	28.87	30.48	+1.61	31.74	+1.26	+2.87
<u>Attitude III: Interest in and enthusiasm for physics.</u>							
Open-ended	35	52.43	47.94	-4.49	47.69	-0.25	-4.74
Intermediate	32	45.59	45.00	-2.59	42.09	-0.91	-3.50
Expository	23	43.52	36.96	-6.56	38.00	+1.04	-5.52

Table 46 shows the mean and variance of the students' scores on the three occasions irrespective of teaching style and for all three attitudes.

TABLE 46

Mean and variance of student scores in attitude questionnaire irrespective of teaching style.

Attitude	n	\bar{z}_1	σ_{z1}^2	\bar{z}_2	σ_{z2}^2	\bar{z}_3	σ_{z3}^2
I	90	30.59	25.69	29.51	28.03	29.86	33.56
II	90	27.59	14.18	29.66	14.49	30.18	15.74
III	90	47.72	114.81	43.38	120.80	43.22	135.51

\bar{z}_1 , \bar{z}_2 , and \bar{z}_3 represent the means of all students' scores on the first, second and third occasions respectively, and σ_{z1}^2 , σ_{z2}^2 , and σ_{z3}^2 the corresponding variances.

Table 47 shows the corresponding mean differences $\bar{z}_2 - \bar{z}_1$, $\bar{z}_3 - \bar{z}_2$, and $\bar{z}_3 - \bar{z}_1$, representing approximately the overall attitude shifts of all students regardless of style during the different stages of the investigation.

TABLE 47

Overall mean differences of student scores in attitude questionnaire.

Period of shift		Third Year	Fourth Year	Third & Fourth Years
Attitude	n	$\bar{z}_2 - \bar{z}_1$	$\bar{z}_3 - \bar{z}_2$	$\bar{z}_3 - \bar{z}_1$
I	90	-1.08	+0.35	-0.73
II	90	+2.07	+0.52	+2.59
III	90	-4.34	-0.16	-4.50

In Tables 45 and 47 the mean differences are taken to represent approximate attitude shifts. It may be

necessary to qualify the interpretation of these mean differences due to the possibility that other factors not so far accounted for may also have contributed to the shift.

Homogeneity of background variables.

Before contrasting the effect of different physics teaching styles by comparing the mean differences for each style shown in Table 46, it is important to establish whether inter-style differences of the independent variables (IQ and social status) are likely to affect the outcomes. Table 48 shows the means of student IQ and social status ratings for the different teaching styles in respect of all students who responded to the questionnaire on the three occasions.

TABLE 48

Mean student IQ and social status rating
for different teaching styles.

Teaching style	n	Mean IQ	Mean social status
Open-ended	35	115.26	3.94
Intermediate	32	112.75	4.22
Expository	23	112.35	4.30
All	90	113.62	4.13

The data shown in Table 48 was obtained in the manner described in chapter 6 (p. 173). The effect of the student variables is estimated in the way described below.

Analysis of variance of inter-style means in respect of each of these variables is used to test inter-style homogeneity in respect of each variable in turn. This

analysis is shown in Tables 49 and 50.

TABLE 49

Analysis of variance of student IQ scores.

Source	d.f.	Sums of squares	Mean square	F
Teaching styles	2	156	78.0	0.92
Students	87	7390	84.94	
Total	89	7546	-	-

$F_{0.05} = 3.10$ for (d.f. 2,87)

TABLE 50

Analysis of variance of student social status ratings.

Source	d.f.	Sums of squares	Mean square	F
Teaching styles	2	2.17	1.09	0.37
Students	87	254.23	2.92	
Total	89	256.40	-	-

$F_{0.05} = 3.10$ for (d.f. 2,87)

The non-significant differences among the means indicated by the non-significant 'F' in both cases suggest that it is reasonable to infer inter-style homogeneity in respect of both independent variables. Consequently they may be left out of consideration in interpreting the student scores in the questionnaire.

Inter-style initial means.

It might seem at first sight that having shown no statistically significant differences among inter-style means for the independent variables, the question of the effect of verbal teaching style on attitude could be answered by looking at the mean differences shown in Table 45 since these represent shifts in attitude after exposure to one of two years of a certain style of physics teaching. This argument, however, takes no account of the possibility that a shift in attitude may be affected by the initial strength of that attitude as indicated in the column of \bar{z}_1 at Table 46, as well as by the subsequent teaching of physics. Thus it is argued that while the initial attitude status cannot be attributed to subsequent exposure to physics teaching, the final attitude status may be related to the initial status. It was therefore thought necessary to covariance out the effect of this initial status.

The use of analysis of covariance permits the initial differences among style means for scores on a first administration of the questionnaire to be taken account of, thus allowing a comparison to be made among

the style means resulting from a later administration of the questionnaire; these later means having been adjusted to take account of the inter-style differences among the initial means. In this part of the investigation covariance analysis is used separately:

- (a) to adjust z_2 scores to take account of inter-style differences among z_1 scores
- (b) to adjust z_3 scores to take account of inter-style differences among z_2 scores
- (c) to adjust z_3 scores to take account of inter-style differences among z_1 scores.

The adjusted sums of squares in each instance are used in the subsequent analysis. The values of F obtained in this way are shown in Tables 54 to 56. In the one case where a significant F results, the adjusted style means are calculated and displayed in Table 53.

The principal assumptions underlying the use of the F test are; (a) that the within group variance does not differ greatly between groups, and (b) that the distribution of scores within groups should be approximately normal. Since these conditions are fulfilled in the case of scores based on student responses to the attitude questionnaire, the use of parametric statistical techniques such as covariance analysis and F is regarded as appropriate in dealing with these data.

The specimen calculation shown below indicates how, in the case of Attitude III, the style means of z_2 scores on the second administration of the questionnaire, at the

end of the students' Third Year, are adjusted to take account of differences among style means of z_1 scores on the initial occasion at the beginning of Third Year.

Specimen calculation.

Attitude III (An interest in and enthusiasm for physics).

Analysis of covariance of z_2 scores with z_1 scores as covariate.

1. Sum of squares and sums of products both 'within' styles and 'total' are calculated for z_1 and z_2 ; using the method described by Lindquist (1956, pp.57 and 319).
2. The data calculated in (1) above are used in the first analysis shown below in Table 51.

TABLE 51

First analysis.

Source	d.f.	Sums of squares		Sums of products $z_1 z_2$
		z_1	z_2	
Teaching styles	2	-	-	-
Students	87	8892.029	9068.845	5413.379
Total	89	10218.056	10751.156	6811.444

Z_1 and Z_2 denote the sums of squares of z_1 and z_2 respectively and Z_1, Z_2 represents the sum of products of z_1 and z_2 .

3. The data from Table 51 are used to find (a) the error sum of squares 'within' styles $Z_{2(W)}^1$ about each 'style regression line', and (b) the error sum of squares $Z_{2(T)}^1$ about the 'total regression line',

$$\text{where } z_{2(W)}^1 = z_{2(W)} - \frac{(z_1 z_{2(W)})^2}{z_{1(W)}} \quad (i)$$

$$\text{and } z_{2(T)}^1 = z_{2(T)} - \frac{(z_1 z_{2(T)})^2}{z_{1(T)}} \quad (ii)$$

$$\text{giving } z_{2(W)}^1 = 9068.843 - \frac{5413.379^2}{8892.029} = 5773.232$$

$$\text{and } z_{2(T)}^1 = 10751.156 - \frac{6811.444^2}{10218.056} = 6210.589$$

4. The adjusted sums of squares of z_2 ; $z_{2(W)}^1$ and $z_{2(T)}^1$ are used in the final adjusted analysis shown in Table 52.

TABLE 52

Final adjusted covariance analysis of z_2 using z_1 as covariate.

Source	d.f.	Sum of squares of z_2	Mean square	F
Teaching styles	2	437.357	218.679	3.26
Students	86	5773.232	67.131	
Total	88	6210.589	-	

$F_{0.05} = 3.10$ for (d.f. 2,86).

The significant F may be interpreted as indicating that when inter-style differences of initial strength of attitude (z_1 scores) are removed, for Attitude I the inter-style means of z_2 scores after one year of physics teaching show a significant difference at the five per cent level among teaching style means.

5. The style means of students' z_2 scores are individually adjusted in the way shown below.

The experimental mean of $z_1 = \sum \frac{z_1}{\sum n} = \bar{z}_1(T)$ is calculated;

where $\sum z_1$ and $\sum n$ are summed over all three styles,

giving $\bar{z}_1(T) = \frac{4295}{90} = 47.72$. The regression coefficient

$b_{z_2 z_1} = \frac{\sum z_1 z_2}{\sum z_1^2}$ is calculated using the data displayed in

Table 51, giving $b_{z_2 z_1} = \frac{5413.379}{8892.029} = 0.61$. These

values are used in the table of adjusted means, Table 53.

TABLE 53

Table of adjusted style means of z_2 with z_1 as covariate.

Teaching style	n	\bar{z}_1	$\bar{z}_1 - \bar{z}_1(T)$	$b(\bar{z}_1 - \bar{z}_1(T))$	\bar{z}_2	$\bar{z}_2 - b(\bar{z}_1 - \bar{z}_1(T))$
Open-ended (1)	35	52.45	+4.71	+2.87	47.94	45.07
Intermediate (2)	32	45.59	-2.13	-1.29	43.00	44.29
Expository (3)	23	43.52	-4.20	-2.56	36.96	39.52
Total	90	47.72	-	-	43.58	-

The last column shows the adjusted means of z_2 .

6. Analysis of the differences among the adjusted style means is carried out using 't' and the appropriate standard error described by Goulden (1952, p.157) and given by the expression:

$$t_{12} = \frac{\bar{z}_{21}^1 - \bar{z}_{22}^1}{\sqrt{\sum \frac{z_{2(w)}^1}{n-4-1} \left[\frac{1}{n_1} + \frac{1}{n_2} + \frac{(\bar{z}_{11} - \bar{z}_{12})^2}{z_{1(w)}} \right]}}$$

where \bar{z}_{21}^1 and \bar{z}_{22}^1 are the adjusted style means of z_2 for styles (1) and (2) respectively; $z_{2(w)}^1$ is the adjusted sum of squares of z_2 'within' styles; \bar{z}_{11} and \bar{z}_{12} are the style means of z_1 for styles (1) and (2) respectively; n_1 and n_2 are the numbers of students in the styles groups and $z_{1(w)}$ the 'within' sum of squares of z_1 .

Comparing the adjusted means of z_2 for students taught in the open-ended style with those taught in the intermediate style gives:

$$t_{12} = \frac{45.07 - 44.29}{\sqrt{\frac{5773.232}{86} \left[\frac{1}{35} + \frac{1}{32} + \frac{(52.43-45.59)^2}{8892.029} \right]}}$$

leading to $t_{12} = 0.373$ (d.f. 65) which is not significant at the five per cent level, ($t_{0.05} = 1.669$ one-tailed test).

The corresponding values of t in the other analyses are:

Comparison between open-ended and expository styles

$$\times t_{13} = 2.387 \text{ (d.f. 56)}$$

Comparison between intermediate and expository styles

$$\times t_{23} = 2.128 \text{ (d.f. 53)}$$

\times significant at $p < 0.05$.

This analysis shows that the adjusted mean on the Likert scale measuring Attitude III is significantly lower for students taught in the expository style than the adjusted mean for students taught in the other styles at that stage in the investigation (end of Third Year). It is the only significant result in this part of the study, as Tables 54 - 56 indicate.

The analyses of covariance described above in paragraphs 1 to 4 are carried out over all stages of the experiment for all three attitudes. Tables 54 to 56 show 'F' for these calculations.

TABLE 54

'F' for analysis of covariance of z_3 using z_1 as covariate.

Attitude	I	II	III
'F'	2.74	0.51	3.26
Significance	n.s.	n.s.	sig. at 0.05

n.s. denotes 'not significant at the five per cent level'.

$$F_{0.05} = 3.10 \text{ for (d.f. 2,36).}$$

TABLE 55

'F' for analysis of covariance of z_3 using z_2 as covariate.

Attitude	I	II	III
'F'	0.60	1.72	0.35
Significance	n.s.	n.s.	n.s.

TABLE 56

'F' for analysis of covariance of z_3 using z_1 as covariate.

Attitude	I	II	III
'F'	2.64	1.51	1.39
Significance	n.s.	n.s.	n.s.

The significance of differences among inter-style shifts of attitude occurring during the first year of the main investigation is indicated in Table 54; these occurring during the second year of the main investigation in Table 55; while Table 56 shows the results of the significance test of style differences among attitude shifts over the two year period.

DISCUSSION OF RESULTS.

It is generally recognised that evaluation of the attainment of educational objectives in the affective domain is unlikely to be reliable. Attitudes to school subjects among students are probably fickle. The proximity of examinations, holidays and so on may influence student responses to attitude scale questionnaires or to other attempts to measure attitudes. Students who have reason to believe that they are currently successful in physics are likely to respond in a favourable manner to a questionnaire designed to assess their enthusiasm for the subject. Self-awareness of high attainment in the cognitive domain is likely to be an important factor in determining student attitudes in

the affective domain.

Lindsay (1967) found that college students who are successful are more likely to express satisfaction with the course they are following than students who are not successful. He suggests that there is an interaction effect between achievement and satisfaction rather than a causal relation.

Among other factors that may affect shifts in attitudes towards physics on the part of students in secondary schools are; (a) the physics curriculum, (b) student maturation, (c) aspects of the physics teacher's behaviour other than his verbal style, (d) the influence of teachers of other subjects especially teachers of subjects related to physics such as mathematics and chemistry, and (e) changing career intentions etc. While recent research into some of these aspects has already been discussed in earlier chapters the effects of others would seem to be difficult to predict. Such effects may not result directly from the students' physics lessons at all. A student who at age 14 years has no definite career in mind may have decided two years later to seek a career in medicine, perhaps having discovered that a school qualification in physics is essential for him to achieve his goal. For that reason he may respond in a favourable way to a questionnaire designed to assess his 'liking' for physics. Another student who has made a different career decision which does not require him to obtain a physics

qualification may respond in a hostile way to the same questionnaire.

Welch (1969) examined the correlates of course satisfaction of high school students following the Harvard Project Physics course. The criterion instrument used was the Course Satisfaction Scale of the Project Physics Student Questionnaire. Students were given two tests of cognitive attainment in physics at the beginning and end of the course. The results indicate that course satisfaction in physics is significantly related ($p < 0.01$) to success in terms of achievement gains but not to the perceived difficulty of the subject. Welch suggests that low grades in physics, indicating that mastery has not been achieved, lead to low course satisfaction.

It seems probable that some physics attitudes such as 'I like physics' are quickly developed but are as quickly lost. Others such as an awareness of the pervading importance of physics which may have a cognitive element, probably take longer to establish but once established are less likely to disappear.

In view of the possible hidden factors not considered in this investigation, it is perhaps to be expected that in general there seems to be little evidence to suggest that the aspect of the physics teachers' style studied here has an appreciable effect on the attitudes measured.

According to the results shown in Table 45 (in which no account is taken of inter-style differences in

the student variables IQ and social status and in which differences among style groups in initial strength of attitude are ignored), it appears that students taught in the intermediate style show an increase in awareness of the significance of physics throughout the period of the investigation while students taught in the extreme styles show an overall reduction in scores during the same period. All three styles show approximately similar increases in mean scores as regards the development of an attitude of objectivity, although it cannot be ruled out that such a gain is due to maturation. The largest shifts indicated in Table 45 are in the scores on the scale measuring the student's interest in and enthusiasm for physics. For this attitude all teaching styles show a reduction in mean scores over the two year period; again the effect does not seem to be related to teaching style.

Table 47 indicates that when teaching style is ignored there is a slight overall reduction in mean score in the attitude scale associated with an awareness of the significance of physics in everyday life, (Attitude I).

These results, although interesting in themselves do not form a central part of the present study which is concerned with a particular aspect of teacher behaviour, the 'directness' of his verbal style, and its effect on the attainment of educational objectives in the cognitive and affective domains. It is, however, interesting to note that other workers investigating

affective changes in physics students have found effects similar to some of those suggested by the results in Tables 45 and 47.

Mackay(b)(1971) investigating the effect of exposure to two years of PSSC physics on Australian secondary school students, a study referred to in chapter 3, reports a slight but significant decrease in the mean score on a Likert scale measuring enjoyment of physics as well as on one measuring student perception of scientists as normal people. This study was replicated, again in Australia, by Gardner(a)(1973) who also used an attitude scale employing the summated technique devised by Likert. Gardner reports over a period of about nine months a very significant decrease in mean score ($p < 0.001$) in the response of the students to the scale concerned with enjoyment of physics. The data shown in Table 47 for mean scores in Attitude III suggest a very similar effect. It may be that a loss of enthusiasm on the part of the students of a subject during the period of study is a general phenomenon not related especially to physics or to any particular aspect of the learning milieu of that discipline.

Tables 54 to 56 show that when homogeneity of the controlled student variables IQ and social status has been confirmed (Tables 49 and 50); and after inter-style differences in initial strength of attitudes have been covarianced out; there remain no significant

($p < 0.05$) inter-style differences in shifts of attitude either for awareness of the significance of physics or for the development of an attitude of objectivity. This is true for both periods of the study and overall. It must therefore be concluded that development of these attitudes is probably independent of whether the physics teacher adopts an open-ended or an expository style.

It is difficult to explain why the one significant result in this investigation of the interaction between style and attitude should occur only during the first year of the main study (Tables 52 and 53) and not be repeated the following year. The significantly greater loss of interest in and enthusiasm for physics on the part of students taught in the expository manner compared with that shown by students taught in the other styles during Third Year would be in accord with the expectation of proponents of discovery methods of science teaching, who claim that students find the expository style inhibiting and dull and are not fired with enthusiasm as a result. The relative stability of this attitude during Fourth Year may be due to a feeling on the part of the students that they were likely to be successful in the Certificate examination at the end of that year. Since all students who responded to the questionnaire during Fourth Year were assured of a chance of taking the examination (the final administration of the questionnaire took place two months before the SCE examinations) this sense of

anticipation of success might have influenced their responses to Attitude III. On the other hand, students taught in the expository style may have responded in different ways during Third and Fourth Years due to a maturation effect. The expository style may be more appropriate with older students.

Perhaps there are other factors more important than those studied here in determining student attitudes to physics. Some recent work reported by Gardner(b)(1973), the same researcher quoted earlier, suggests that there may be an important interaction effect between student and teacher personality factors and that this effect is crucial. From a study of high school students in Victoria, Australia, Gardner asserts that the decline in enjoyment of physics reported elsewhere may not apply in the case of.....

'intellectually intense students with intellectually stimulating teachers'... He concludes that the more serious a student is the more likely he is to maintain favourable attitudes to physics and especially when taught by a serious teacher. On the other hand, Gardner suggests that the attitudes of the less serious students which decline in any case, do so even more markedly when taught by a serious teacher.

If this is so then the student's perception of his physics teacher's personality is perhaps more important than some other variables of teacher behaviour. The generally non-significant findings

reported here suggest that the effect of teacher 'directness', the teacher behaviour variable investigated, may vary with the personality of the student.

CONCLUSIONS

"In education, unfortunately, there is great furore about whatever is announced as the latest trend, and the schools seems to career erratically after each Pied Piper in turn. This giddy chase keeps them almost beyond earshot of the researcher standing in his tiny, laboriously tamped patch of solid ground, crying in a pathetic voice, 'Wait for me! Wait for me!'"

Cronbach, L.J.

It has to be admitted that there is a paucity of evidence to support the premise underlying the philosophy of recent curriculum development in science education. Almost every new trend in physics teaching within the last fifteen years has favoured the still largely unsubstantiated assumption that physics teaching based on the discovery learning strategy is good and that expository physics teaching is bad. It may be so but confirmatory evidence is lacking. The present research has been undertaken with the intention of testing one aspect of this hypothesis.

Scotland has been in the forefront of recent curriculum development in the field of science teaching, and has a body of mainly young physics teachers generally committed to modern teaching methods. The syllabus taught in the schools typifies the discovery approach. It is therefore surprising that according to the investigation described here a broad spectrum of verbal styles still

exists among physics teachers (see Chapter 5). Perhaps this finding underlines the danger of exaggerating the effect of curriculum development on what actually happens in the classroom. Analysis of the data derived from classroom observation leads to the conclusion that for some of the time all physics teachers find it necessary to employ an expository verbal style. This is probably due at least in part to the nature of the subject as well as to the institutional constraints of the classroom situation. Comparison with data from similar studies indicates that the range of verbal styles displayed by Scottish physics teachers is similar to that of physics teachers in other parts of the world, (see Chapter 5, p.129). The data also suggest that physics teachers everywhere talk much more frequently to the class than they allow members of the class to talk to them. It may be argued that the discovery aspect is related to the experimental work which the students carry out and that this is divorced from verbal interaction between teacher and students. Nevertheless this verbal interaction must be linked to the experimental work of the students and provides a firm opportunity for the teacher to guide the 'discovery' activity of his students, and by his open-ended questioning style to stimulate in them a desire to pursue their experimentation in a spirit of enquiry. A teacher who regularly foregoes this opportunity by using a 'direct' verbal style may not be encouraging the discovery style of learning.

From teachers' responses when interviewed (see Chapter 5, p.130) it seems that there is no clear cut link between the teacher's perception of his authoritarian role in the classroom and his use of an authoritarian verbal teaching style. Although the teachers identified as possessing a very open-ended verbal style express more democratic views in general when interviewed than do the others, all are agreed on a number of topics including several which imply a basic disbelief in the ability of their students to profit from discovery teaching methods in physics. Could it be that, as several researchers have contended, there is really very little enquiry learning taking place and that when it does occur, the teachers practising it may be doing so without conviction?


Perhaps it is proper to conclude that although the extend to which teachers adopt a verbal style designed to inspire discovery learning varies widely, the style of most physics teachers owes much to tradition.

When the experimental data related to tests of student attainment in the cognitive domain are analysed no clear cut conclusions can be drawn about the superiority of the open-ended or 'indirect' verbal style over the expository or 'direct' style. Nor is an intermediate style shown to have an advantage over these opposites. There is, however, a suggestion that students taught by teachers who use an open-ended verbal style are more successful in achieving the more complex cognitive objectives than their fellow students taught in a strongly

expository fashion, especially where the test format used in evaluation permits the display of a measure of self expression. It may be that tests structured in the fixed response format which characterises most of the tests used in the present investigation, obscure the difference in achievement between students taught in the two styles contrasted here.

The difficulty of reaching agreement about the ascription of educational objective categories to test items is generally recognised (see Chapter 6, p.162). It may therefore be unwise to dwell unduly on the finding that regardless of teacher style, student attainment in test items associated with objectives low in the hierarchy is markedly better than that in items involving the more complex objectives. The evidence supporting this observation is nevertheless striking and merits further study.

One curious and rather unexpected result is the finding that students taught in the expository style tend to score more consistently in tests of cognitive attainment, especially as regards objectives low in the hierarchy of objectives. Were this to be confirmed in future investigations it would seem to justify the use of an expository teaching style to make certain that students grasp the fundamentals and basic computational skills in physics since it is these which are usually represented by educational objectives at the lower end of the hierarchy. Equally the results reported in



Chapter 6 indicate that to ensure student attainment of the more complex objectives in physics, teachers should be encouraged to employ a variety of teaching modes including an open-ended one and thereby to stimulate their students to practise thinking their way through an unfamiliar and perhaps complex problem.

Measurement of student development in the affective domain is notoriously difficult, not only because some attitudes are transient, but also because their development may depend on a large number of uncontrolled variables, some of which may be concealed or immeasurable. Some interesting shifts in student attitudes are mentioned below but none that on the evidence could be confidently attributed to the verbal style of the physics teacher.

The striking lapse in enthusiasm for physics displayed by the students during Third Year regardless of teaching style is not confirmed by the data obtained during Fourth Year. Does this suggest that some special feature of the Scottish physics course followed in Third Year discourages the students? The negative shift in attitude reported at this stage may simply reflect a student's general disillusionment and indicate that one of his course options selected at end of Second Year has failed to live up to expectations. It would be interesting to know whether such a result, observed elsewhere for other modern physics courses, has been identified for other subjects, especially other science subjects.

In this part of the study reported in Chapter 7, the

one significant finding, which favours the open-ended style relates to Third Year. It might be interpreted as showing that as students become more mature they resist the open-ended style with its emphasis on active student participation in the learning situation.

Although not a primary aim of the study it is of interest to note that the Scottish physics syllabus seems to encourage an ability to make scientific judgments in an objective way. It cannot be ruled out, however, that such a development owes less to a study of physics than to maturation during the period of the investigation.

The evidence adduced here does not support the claim made that the Scottish physics syllabus encourages students to become more aware of the general significance of physics in everyday life. A syllabus which lays greater emphasis on the social and environmental impact of physics might do more to encourage such awareness.

Consideration of the findings as a whole leads to the general conclusion that the unrestricted advocacy of an open-ended style of teaching physics is not justified. The evidence suggests that in some respects an expository style is more effective.

Suggestions for future research.

A small scale study such as that described here can often do little more than suggest a path along which future researchers might direct their efforts.

It is doubtful if a replication of the present study carried out on a larger scale would be fruitful.

Interaction analysis techniques such as that used here (see Chapter 5, p.99) are not ideally suited for use in the observation of physics teaching. Nor does it seem that verbal style as such is related in a simple way to student attainment in physics.

Research cited earlier in the thesis (see Chapter 7, p.225) concerns investigations which focus on the interaction between teacher personality factors and student personality factors. The findings suggest that this aspect is important in influencing outcomes of physics teaching. Since the teacher's verbal style must derive to some extent from his personality it might be useful to study the interaction between teacher's verbal style and student personality. It seems likely that some students respond better to the open-ended approach while others prefer the expository mode. It might be possible to identify particular student personality factors as being more responsive to one verbal teaching style than to another. The difficulty is that, even if this were known, how could physics teaching be organised within a school so that students were matched with a teacher to whom they would respond?

A second possible line of investigation would involve not only a study of the teacher's verbal style but also of the way in which the experimental work of the students is organised. The aim of such a study would be to see how verbal style is associated with the creation of genuine discovery learning situations in the laboratory.

Are frequency of teacher questions and quality of questioning technique crucial teaching acts in the physics classroom? An investigation into the effects of these specific aspects of the physics teacher's verbal style could make use of the same research design as that employed here. In this case frequency and type of teacher questions and the sequential process of questioning would be the observation data recorded. Studies of this aspect of the teacher's style are mentioned in the thesis (see Chapter 1, p.12). The reported findings encourage the hope that an extension to physics might lead to a significant result. If one style of asking questions could be shown to be superior to others there are important implications for the training of physics teachers.

There can be little doubt that what the physics teacher says and how he says it is a matter of central importance. It is likely to provide the impetus for the face to face communication between teacher and students so inadequately and so aridly designated 'classroom interaction'. Such inter-communication may well be more important in determining the quality and the effectiveness of physics teaching and learning in our schools than curricular changes which are inspired from outside the school and which can exert, in the nature of things, no more than an indirect influence on the fundamental quality of communication within the classroom. There is surely a case for further research into this aspect of teacher behaviour.

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APPENDIX I
INTERVIEW SCHEDULE

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Topic No. 1. Learning physics by doing experiments.

What is the teachers' attitude to noise and chaos in class?
Does he think students are learning under these conditions?
Does he prefer to avoid chaos by reducing student experimentation?

What experiments does he think might be done as student experiments in Third Year?

Ask about particular ones; e.g. gas laws with medical syringes, specific latent heat experiment using ice and filter funnels.

Key Question: Does he think that on the whole students learn better by doing experiments for themselves or by watching the teacher demonstrate?

Topic No. 2. Enjoyment of physics lessons.

What kind of lessons in physics do students enjoy?
How does he know that they are enjoying a lesson?
What steps does he take to try to ensure that they will enjoy physics?

Key Question: Does he really regard it as important that students should enjoy what they do in the physics class?

Topic No. 3. Exploring side issues with students.

Does he ever find that a student wants to explore side issues arising out of a physics lesson?
Does it happen often?

What should a teacher do when it does happen?

How does he react to this when it happens?

Key Question: Does he feel that students should be encouraged to raise questions concerning side issues and to explore them?

Topic No. 4. Teacher questioning of students.

How does he generally start off a lesson to a Third Year physics class?

Why does he start in this way?

What does he think of always starting off by asking a few questions?

Why ask questions?

What does he regard as the difference between teaching and lecturing?

Key Question: Does he regard asking questions of a class as an important aspect of teaching physics?

Topic No. 5. Lesson presentation.

Should a teacher have a clearly stated aim before him at the start of each lesson?

How should this aim be expressed?

How would he phrase his aim before setting out to 'do' Boyles' law?

What does he think of - 'To prove to the class that the pressure of a fixed mass of gas at constant temperature is inversely proportional to the volume'?

Key Question: Does he regard the teaching of physics as confirming a series of relations between physical quantities?

Topic No. 6. Open-ended student experiments.

When giving out apparatus for student experiments what instructions should the teacher give?

What would be his aim for a lesson in which students are asked to use trolleys and ticker-timers for the first time?

What would he expect them to be able to do?

What instructions would he give?

Key Question: If the students were given trolleys and ticker-timers and asked to make an unspecified measurement in physics what would he expect them to achieve inside a double period?

Topic No. 7. Homework.

Is he keen about homework?

Does he think that homework affects a student's attitude to physics?

What effect does he think it will have?

Key Question: How does he react to "There is one teacher I know who gives all his classes regular ink exercises: on the other hand I know another teacher who regards any homework as an evil imposition. Where do you stand?"

Topic No. 8. Examinations.

Is he keen on examinations?

Does he think that examinations are reliable measures of ability?

Does he regard them as a waste of valuable teaching time?
What is his attitude towards doing away with examinations?
What does he think of getting rid of pass-fail distinctions?

Key Question: What does he consider would be the effect on his job as a physics teacher if all examinations were abolished?

Topic No. 9. Note-taking.

After his students have carried out an experiment themselves what written record do they have?
Are these notes written in a rough jotter, lab. note-book etc.?

Do the students write these notes in ink, pencil or does he not care?

Are the experimental notes compiled by the students themselves or are they dictated?

Does he think that in taking dictated notes the students' learning is reinforced?

Key Question: How does he react to "Suppose an average group of students took no notes at all during physics lessons throughout Third, Fourth and Fifth Years, how do you think they would do?"

Topic No. 10. Student freedom.

How much freedom does he think students should have in school?

Does he consider they have too little or too much at present?

Should students have freedom to select only subjects that interest them?

Does he feel they should be free to attend classes in a subject only when they feel that the topic that day interests them? That is, should the students draw up their own syllabus?

Key Question: How does he react to the idea that students taking physics study only these parts of physics which interest them?

Topic No. 11. Order and discipline.

Does he like to teach in an ordered situation?

What particular kind of student misbehaviour does he find most irritating?

What sanctions does he take against a student who refuses to do homework?

What does he think of the use of corporal punishment?

Does he think it has an effect on student-teacher relations?

Does he think it is used too frequently in Scottish schools?

Key Question: What would be the personal effect on him if the use of corporal punishment was prohibited?

note: The purpose of the key questions was to ensure that at some stage of the interview the subject was asked to respond in a way that would commit him to take up a position on each topic.

APPENDIX II

TRANSCRIPTS OF TEACHER INTERVIEWS WITH TEACHERS RATED MOST OPEN-ENDED AND MOST EXPOSITORY.

The complete transcripts of interviews with the other teachers are available and may be obtained by making application to the author.

TEACHER H - THE TEACHER RATED MOST OPEN-ENDED.

Q. Now, one of the things you find nowadays, I find, in going out and in lots of schools and under all sorts of different conditions, is that there is a tremendous amount of noise and chaos and movement and activity in a physics class, nowadays, most of the time because of the nature of the teaching technique. One wonders how much learning is actually going on in these circumstances. What do you think about this?

A. I think it is absolutely inevitable that if you are going to leave the children a certain amount of freedom to find out things for themselves, then you are going to end up with children wandering about comparing results, one group with the other, 'what did you get, I don't get that'... this is all part of learning. If you want to define learning in terms of the old Scottish academic idea, of sitting down and taking notes off a board, or talking to the teacher, certainly there is not much of that going on and is that learning really? I think they learn a lot more in the relatively structured chaos if you like, of a properly organised lesson. The lesson has to be organised, it is certainly more difficult to organise, I think, and still keep that chaos if you want to call it.

Q. Certainly one way, of course, of reducing the chaos if one wanted to do this, would be, I think, to reduce the amount of pupil experimentation.

A. Certainly, but can you teach physics, actual

physics, without them actually experiencing physics. An analogy doesn't readily spring to mind, it is like teaching English without using books, isn't it, I suppose that is one possible comparison. I don't think you can teach physics and get them to experience... how do you... In physics you are dealing with reality, you are looking at real situations and a physicist must look at real situations, that is what they are doing, I don't see any other way for it. It is probably more pleasant this way too, but that is beside the point; even if it weren't more pleasant I can't see a better way to do it.

Q. Turning to particular situations, say in the third year, or perhaps the fourth year, depending on how you do it; for example doing the gas laws if you use these medical syringes, in some cases you can create a pupil experiment situation rather than a demonstration. What do you think about that?

A. I would go to some lengths to get a pupil into an experiment situation but, at the same time, there are occasions when a bad experiment can cause confusion and then you have got to compromise. Supposing that the only way that you can really effectively do this is by demonstration then you do it by demonstration, involving pupils all the time of course. If you are careful you keep the number of demonstrations down to a minimum and do them properly and you involve the pupils in these situations too. Personally, I don't do it with the syringes, I found a better way to do it which does

involve the pupils, using a capillary tube; it is quite cheap, you can turn it out that way but on the general point there is a line at which you have to say, well look the children are just messing about here, the experiment is not really teaching them anything; it is not a good experiment, you have got to abandon it and say, well look at this big expensive piece of apparatus I have here, let us try and make it work together.

Q. Now, another one on the same sort of subject material, is the specific latent heat of fusion of ice with the filter funnels, the idea, one of the ideas... the immersion heaters, one of the ideas of this I think was to.. this was seen as a step forward, in that it was going to convert what had often been a demonstration to a pupil experiment. What do you think about that one?

A. It is a borderline one, with a good class you can make that one work pretty well; with a not so good class you have difficulties. It is a complex experiment, you have to correct for this background of heat and so on. Mind you it is getting better with more and more integrated science being taught and more and more of the pupils having some sort of background in biology, where control experiments are used generally. It may be my imagination but I am finding they are taking it better now than they did before. We will have to wait for a year or two to see if it really is the case or not but certainly it is a borderline experiment. Personally I do it but I always find difficulty in getting this one over.

Q. On the whole then would you say that in your view pupils learn best by doing experiments for themselves, rather than by watching?

A. Oh yes! This is almost a statement of belief I would have thought.....

Q. What factors influence pupils in learning, or what sort of things does a teacher do that allows pupils to learn. Some people say, it must be said that they are very often people outside the classroom, that one of the most important things is that human beings learn things best when they are enjoying themselves. Do you consider it important that pupils enjoy physics?

A. Yes. They can't enjoy themselves all the time; there comes a time when they have got to get down to something which is a little more unpleasant in terms of hard slogging work but if they enjoy the rest of the time and if they do enjoy the time they spend in the physics classroom then they have the motivation for doing this work; if they see it as being relevant and if, as I say the rest of the time, when they are doing experiments, if they have a relatively large degree of freedom and so on, they will enjoy it. This helps them when it comes to the slogging bits. Anyone who says you can get away without the slogging bits isn't teaching, they are just letting the children play about. You have to get both things there. The problems are unpopular but they are necessary.

Q. Do you think one can tell when the pupils are enjoying physics? I am not sure I could have told you this but people say you can, when they are enjoying a lesson, how is one to tell?

A. Perhaps I am just taking this on the surface level; I can't say I have thought specifically about this problem. Certainly I could say if a class weren't enjoying a lesson, or maybe appreciating a lesson is a better word. You really have to appreciate it to a certain extent to enjoy it - certainly if they sit there cold and unresponsive and they look at you.

Q. Do you feel there is one kind of lesson, any particular kind of lesson in physics they tend to enjoy on the whole more than others?

A. Well, I think perhaps appreciate is a word we use more often. The kind of lesson they appreciate is something which the whole lesson has got some kind of a shape; if they are doing an experiment, at the beginning they don't know what the answer is going to be, this is the situation we strive to achieve time after time. We don't achieve it as often as we think we do or as often as we might, if they start off... if you start off by saying, well, look what do you think will happen here; quite a complex situation perhaps and they give you all sorts of ideas and you begin to get them saying 'well, perhaps this will happen, perhaps that will happen', if they do the experiment and it is a good experiment and they don't have to come to you in the end and say

'please sir, what should I have got here?'. But if it is a good experiment and it works and suddenly things click for them then they feel... 'I have done this, I have discovered that this is the answer', it is perhaps a cliché these days, but if they actually discover things for themselves and the whole lesson takes a bit of shape and they see a bit of point in it, then I feel they will go out that door and feel more satisfied than when they came in. Certainly a lot more of a physicist than when they came in.

Q. Sometimes a pupil wants to explore some side issue that arises out of a lesson. People say this happens often but certainly I don't think it does but it does happen sometimes; do you find it happens often?

A. No, definitely not. I find one of the dangers for the less able pupil and the pupil who perhaps has not seen the point of what we are trying to do, or perhaps is unable to concentrate on it, I find that he will often sidetrack himself and sidetrack you and if you were not careful you might think he was going off and exploring another line of discovery. He is not really. The number of times when a really good pupil, or the pupil who really has got a grip of what is going on here - the number of times when he wants to push the frontiers of his knowledge backwards along a direction unstructured by you isn't terribly often. It does happen, particularly later on.

Q. How do you react to it when it does happen?

A. It depends. Unfortunately we are working to an examination syllabus and we have only so much time. If this pupil, and obviously this class is in the situation where this time can be spared then fair enough, you let him go on. It is probably one of the most valuable parts of the actual physics for him. Sometimes I try and arrange it if he is doing this..... I remember once for instance doing electric motors and we had a particularly good class and the idea came up, it is a bit jerky the way it is running, and one particular group said 'could we get over this in some way?' - the idea came through eventually with a bit prodding of winding two coils at right angles to each other, and this went on and on until eventually we did this at lunch times and after 4 o'clock. This is how we managed to find time for it. They had an eight coil motor running very smoothly and very powerfully with one of these wee electromagnetic kits. I think this is the kind of thing you have got to find time for, you can't find time in four periods a week.

Q. Now... you might say, 'you shouldn't need to ask me this question because you have seen me teaching often enough' but if you would let me ask you, you probably don't think about it, how do you regard... what do you think you normally do to start off a lesson to a third year's physics class, apart from the formalities 'come and sit down'....

A. I probably start off, and as you say this is something I don't think about... It depends on what kind of lesson it is. I probably start off where they finished last day, and see how much they have picked up last day.

Q. How do you do this, how do you actually do, what do you say?

A. I suppose it is the classic, 'what were we doing last week', or do I?

Q. That is asking the question, yes.

A. It depends on how far the lesson is following on this... I usually try to get something tied up. On reflection I usually try to get something tied up in a double period and supposing then it would be ideal if you were starting something new, if you are sure you have the previous one tied up then you might start along a different line altogether. One would hope that when you start off the lesson if the end point of the lesson isn't immediately obvious. So it would really depend, for instance, I can always remember last week there, this week now, starting off with one class, I was starting off momentum that one I started off talking about rugby players standing in the middle of a field bashing against each other with no connection with the previous lesson; on the other hand - it is a difficult question to answer that one.

Q. I think what you are really saying is that there is no real specific way, is there, you know, any fixed formula?

A. Well, I don't have a fixed method. I know some teachers who come in and say 'now here's two questions of what we did last day....', possibly effective but..

Q. Certainly, asking questions, now to come to that in a more general way. This is something I tell the students in the college to do anyway, rightly or wrongly, probably wrongly but anyway this is what I say, I tell them it is important to ask questions in the classroom. What do you think about that?

A. It is absolutely vital to ask questions in class. I suppose one could catalogue the reasons for doing it. Unless you ask questions and get some kind of feed-back from the class you are not sure if the class are with you and you are also not sure what the class are thinking and the number of this...is probably being side-tracked into a very small point, the whole issue... the number of misconceptions that arise in a physics class, the average physics class is incredible. This is one of the few ways to find out where the misconceptions are. To find out if you are teaching effectively you have got to ask questions. You wasn't be afraid of the answers you get too; it is not a case of asking questions which have a right or wrong answer; it is important that you really find what the misconceptions are and how far they had got by following up a line of

questioning with them. I don't know, I haven't really analysed my own style of teaching, but I think I ask a lot of questions in class. I probably rely on them quite heavily to find out what the class are doing as opposed to examining written work.

Q. Turning to a question of... I suppose we have been talking about this already, though not quite specifically, the forethought that goes into presentation of a lesson. What do you think of before you start? There is all this talk about aims and objectives and the teacher ought to have a clearly stated aim. Well clearly an experienced teacher isn't going to write down the night before on a bit of paper what his aim is but supposing you did this, or you were advising someone to do this - take Boyle's Law for example as an experiment that was to be done the next day, and you had to set down in some form of words your own intention for yourself, not what the pupils will write in their books or whatever, of what you thought you were going to do at that double period, what would you think of the following - 'to prove to the class that the pressure of a fixed mass of gas at constant temperature is inversely proportional to the volume', 'to prove to the class, bla bla bla.....' Now, your intention, this is what you are going to do - what would you think of that?

A. Well, if that is the objective you set yourself you certainly can fulfil it very effectively. It would be quite easy to do it but it is rather unimaginative,

it would be rather dull for the children, it would not tell them very much. You might get them into a situation where they certainly could regurgitate Boyle's Law to you but would they really appreciate Boyle's Law. I would not set myself that kind of aim.

Q. Would you... it is maybe unfair to ask you this on the spur of the moment, I thought about this in leisure.. how would you... can you think of a way you might frame your objective?

A. I think.... this is the pupil objective we are talking about, I think I would have a general objective at the back of my mind all the time, to help them in logical constructive thinking, and so on, and appreciate the physical situation, but that is presumably a different question.

Q. Yes, it is what you...

A. A specific objective for this lesson, for this content - centred lesson (that's right) then what I would probably do is say to myself, right 'help the pupils to understand, help the pupils to discover, or to achieve some kind of understanding of the behaviour of gases, how the volume of a gas changes if you change the pressure of a gas.' I think, one doesn't want an objective to be too loose, one has to see if one has achieved it or not, that is one of the points of objectives; at the same time my objective would be a more general.... I probably wouldn't mention Boyle's Law in my objective at all. I don't think it is

important that they should know that pressures and volume have anything to do with a chap called Boyle.

Q. Yes. Now moving on to the question of - we said earlier and we agreed, that pupil experimentation nowadays is certainly much practiced and is probably a good thing; what kind of instructions would you give; if we take a specific example, you are giving out to a class, maybe third year, for the first time, ticker timers, they may have encountered the trolleys before but not the ticker timers. Now it is the first time they ever had these things. They have been given out for the first time to use by themselves, either with or without trolleys depending on your taste or the different context of timing or something, what would you expect them to do, what would your aim, again, be? What would you expect them to do?

A. I wouldn't treat the ticker timer as being a separate piece of something to be studied itself, it is very much a tool at that stage. Practically, I probably would have to spend some time explaining how you can adapt a lab-pack. I don't think the idea of just saying 'plug in here and plug in here' works; you have to explain why you don't plug in there, why you use a.c. It does take some time to get them roughly familiar with the principles of using the ticker timer. I don't think I would spend very much time explaining how the ticker timer works, that is something that will click into place at a later part of the course. As long as they have the general principles.

Q. What would you expect them to do once you had explained this, what would you expect them actually to do? What kind of experiment if any?

A. Well, the way I should do it... the ticker timer is an interval timer and I relate it to the measurement of speed and I would expect them to take the classic one, I suppose, take a piece of ticker tape and streak across the classroom with a piece of ticker tape attached to them and then sit down and analyse their motion, ask them to run, or to walk, or to jerk the tape, fast, slow, fast, or something like that, and see if they can use the tape to draw a graph of their motions, hammering the point home, this is a very difficult point to get home to them; you have to, got to do it, time and time again; how you measure speed by measuring distance over time and the business of dividing by 50 for instance, it is pretty dreadful. That would come later. You do a graph first and then you work on that calculating the speed and so on.

Q. Now, supposing on the other hand you gave out the ticker timer and lab - packs and bits of paper and switches or whatever and you simply told them, before you have given the stuff out, you have told them 'here is a device that we call a ticker timer', or 'here is a device', 'you can use it to make some sort of measurement that we are interested in, in physics, and I am not going to tell you what it is, away and try and measure something with it.' What would you

expect them to achieve inside a double period with that sort of instruction?

A. Not very much, it is too general. You want them to discover things but you have to point them in the right direction, give them a push. You might get something from an exceptionally good class, get something out of it. Even with structured teaching it is difficult enough to get something out of this... to use ticker timers. Giving them that kind of situation. Give that to a sixth year class, give them those instructions, then you will get something out of them if they have never seen a ticker timer before. Give them a sort of black box, where nobody will know what is happening, with a few knobs on it and say 'what do you think you could use that for?'; and then you will get something out of it because they are relatively mature or they should be in their thinking as scientists. But, give that to a third year class and they will lose interest very quickly too because they won't be achieving anything and if they are not achieving anything they won't be terribly interested in what they are doing. That is generally, of course, you may get the odd one or two who are outstanding.

Q. Now going to the question that often causes a bit of controversy, and that is homework. We talked about what affects the way in which pupils learn and the condition under which he best learns, how about the effect of homework - do you think getting homework

affects the pupil's attitude - do you think it affects their attitude to physics?

A. Oh yes, it affects their attitude; that is not the real reason for giving it of course. But certainly if they have a subject in which they don't get homework, putting it in the context of school, that they won't do any homework they won't do anything at home at all and certainly a lot of the stuff they do in the class requires consolidation of the work at home. I don't give a lot of homework. I try to get them into the habit, trying to form the habit of doing experiments and getting the bones of the experiment down when you are actually doing it and then going home and saying, 'well what was all this really about, can I write a brief description of the principles?' - not the usual thing - 'we took a Bansen burner' but supposing you are doing kinetic energy explaining why you are using a wee set of goal posts and elastic bands. Problems I think are important to them. They don't have time to do problems in class. What I generally do is have a sheet with a problem on it and I give them all out a sheet with a problem on it and they do the problem on the back of the sheet. I take the sheet back in and I look at the problems. It tells a lot on how the class are thinking; also it tells them a lot on how much they understand of what they have been doing

Q. If we think of this in terms of a spectrum there is a teacher I know who gives all his classes, in

years three, four and five, a regular ink exercise to be handed in every week - on the other hand there is another bloke who reckons that homework is an evil imposition and is socially a bad thing and to give homework to young people to do in their leisure time is absurd. Where would you say you stand in this general spectrum?

A. I don't give them ink-exercises because there is not much point in neatness and tidiness to be learnt as homework, this is something they should be imbibing all the time at school certainly but there is no point in ink-exercises nor do I tend to give it out regularly. On the other hand there is a tremendous argument put forward against it, even socially... I probably lie somewhere in between. Homework is very useful, it tells you a lot and it tells the pupil a lot. It is also a very effective teaching aid and I use it, I don't use it a lot mind you. I suppose if I give them one problem a week and maybe some weeks they wouldn't have any problems to do from me; it depends on what they are doing at the time. I wouldn't say I have any definite rule on this one..

Q. But probably in this general spectrum you would be, you say, nearer which end?

A. Nearer? The left... (not necessarily political...)
No.

Q. Now coming to that other vexed question, that of examinations; now do you think examinations, would you

agree with the statement that examinations are reliable measures of attainment in physics?

A. It depends how you measure, how you describe attainment. It depends on the examination. It depends on the thought that has gone into it. There is no general answer to that question.

Q. Supposing it was a good examination?

A. Then it can be fairly reliable. We would never try to claim 100% reliability for it. But a good examination on a specific part, testing specific objectives and if what you are after is, in answer to the question, how well have these pupils attained these objectives, then you probably would get an answer to that one. To try to answer the question 'how good a physicist is this person?', by an examination is a wee bit optimistic, especially at school stage. It does give you some measure, let us face it, possibly all the pupils who are good at physics tend to get 'O' grade physics and possibly all the pupils that are rotten at physics tend to fail 'O' grade physics but that is taking the two extremes; in between I wouldn't want to place too much reliability on examinations; we all know the case of the odd pupil in the class who seems to respond very very well in class but when he gets into an examination room there is nothing comes out. Very often there are reasons for this, reasons that are not terribly obvious but still they do occur. I am not anti-examinations, they are very useful things

but I would not like to place too great an objective status on examinations.

Q. What would be your attitude then to doing away with them entirely; all kinds of examinations within the school system, both external and internal?

A. That is a question that has implications away beyond the physics realm, the department of physics, it has implications away beyond the school, and, I think to discuss that question you would have to discuss the whole structure of society. But, as far as affecting the teaching situation goes, which is a very specific part of the whole question of examination, as far as affecting the teaching situation you certainly would lose a little of the drive; it would let you open up your syllabus, you could probably teach more physics; whether pupils would learn or not that is a different question. I may be very presbyterian in this and think of original sin when I say this but whether pupils would learn quite so much without the knowledge that one day they are going to sit an examination without a specific objective in front of them, it is a question I would not like to answer. I suppose with an intensely charismatic teacher with fantastic personality, teaching physics as it really ought to be taught, as we all know it ought to be taught, those children would be very strongly motivated. But in the practical situation, me at the class on Monday morning I wouldn't like to do away with them all together.

Q. What about being a little less radical and not doing away with them but doing away with pass/fail distinction. There has already been some moves in this direction in, for example, the sixth year studies. Some people would say this is a move away from the pass/fail;; what would you think about that?

A. I think the whole question of examinations, national examinations, needs to be looked at; there is no doubt about that whatever. There is no terribly clear policy on this, at least not at the shop floor level as regards percentage of passes and so on. Something needs to be done there. It is a very big question and I have no simple answer to this. Certainly I am convinced something needs to be done there and probably the answer lies along the 'grades' direction. I would not like to say it is specifically a simple answer but the answer probably lies along that direction somewhere. I think you are in a straight jacket, you are lumbered with the university requirements for 'Higher' grade at a constant level and yet at the other end you have the ROSLA pupils arriving and you have the S.C.E. 'O' grade exams which were originally designed for about 30% or the top 30%... now you have the whole spectrum of the school in there. It must be looked at, it has got to be looked at. I have heard suggestions, for instance, of schools awarding their own exemptions, and so on; this is a possibility. There are all sorts of implications which will have to be looked at. I have the kind of feeling

the kind of hope if you like as well, that the answer does lie along this direction somewhere.

Q. To bring this matter of examination to a more specific personal level what would you consider to be the most likely effect on your day to day job as a physics teacher in school, if all examinations were done away with; how would it affect what you do?

A. I would have to work a lot harder, I think, to keep the pupils' interest. I would certainly have a lot more freedom in as much as I could say, well look.. now let me see, while I think about this one. Are my ideas of what physics is the same as the exam board's idea? I would have to ask that question right away. So far I have used them as a crutch: and there are some questions I have not asked myself, it is in the syllabus and therefore I have got to teach it, therefore the question doesn't arise; this is the major part of the syllabus and the question doesn't arise; do I want to teach this or not because I have got to, or is this physics or not because I have got to. I would probably want to spend a year in hibernation thinking of this one. I would have to work an awful lot harder thinking about it. Then there is the actual classroom situation too. The pupils wouldn't be in here with this motivation and I would have to make sure they had some other kind of motivation; which I hope they have, don't get me wrong, I hope they are not just here to pass the examination but that is probably the reason they are here in the

first place; and you have to work on that one. I hope that during the average period they don't think to themselves 'I have got to learn about this because it might come up in the examinations.' I hope they don't think like that. Yet on the other hand it is always a crutch.

Q. Yes. Now to turn to something more specific, specifically informational as it were, not so much personal opinions, rather what happens. After the pupils in your class, your own particular class have done a pupil experiment, what record do they actually have, what written record?

A. This varies. Again you try to take crutches away from them as they come through the school, I think. These work sheets in the first and second year that are published or that you make up yourself are a good idea; they leave the pupil, especially the pupil of lesser ability as far as written English is concerned anyway, it leaves them more freedom to think about the science going on. In the third year, also in the first and second, I attempt to try, particularly towards the end of the second year, to get them to write a wee bit more, to get into the habit of writing down experiments, trying to put their ideas down on paper, trying to put conclusions of their own down on paper; at the beginning of the third year I try to, I still use work sheets, but very occasionally for what might be a complex experiment but even there my work sheets tend to have a lot of blanks

in them for the pupils to write - in the case of a complex diagram, or a complex table, after we have worked out the table with the class, I tend to chuck these work sheets at them and say, 'there you are, save you doing all that.' I tend to teach them a structure of writing up an experiment. I tend to almost say, 'look you really want to have a title for an experiment.' We may discuss the title together and decide what it will be but I tell them we really ought to have a title for the experiment so that you know what it is about. A good sketch speaks volumes for instance. I then say 'leave a space there for description and when you get home tonight or at the end of the period when you have finished it, write down the things you think are not obvious from the sketch and are really quite important about this experiment.'

Q. So they do this for themselves then, they compile their own notes to some extent?

A. Yes, to a greater and greater extent as they go through the school. To begin with.... if you just asked them a class at the beginning of the third year, there is a sudden change from the second, 'look we've done this experiment, you have done this experiment, go home and write it up' you would get absolute chaos, you wouldn't get anything at all. I attempt to try and make sure that the conclusions they have got down are all the same thing. I do this by either saying 'well let us work out a conclusion together for this experiment',

or at the end of a section by saying, 'well look, I have got a summary sheet here which roughly summarises all the important things about this section we have done', and I give them that. Again, as they get farther up the school I don't like to do that kind of thing because to me one of the important points about when they come to study for exams is the process through which they go, asking themselves, 'what was this section really about, what are the important things we did in this section of work, what points are really coming over?' And, if they can reduce all the physics they have done in two years to say four or five sheets of paper, then they have gone through a very important learning experience in doing that, which I would be doing wrong to short circuit. So to summarise I suppose, increasingly I would like to leave them more and more as they learn how to do this kind of thing so that they can understand it themselves in a couple of weeks time, then I would try to leave them more and more to do their own writing up.

Q. You don't use dictated notes then to any real extent?

A. No, I don't use them at all.

Q. Some people say that pupils actually learn, that they get their learning reinforced by writing it down, writing dictated notes, that this helps them to actually learn.

A. I can't see how that is. They are too busy thinking about what you are saying, how to spell this

word; I can see the point about making that statement about, perhaps, issued notes, although my own feeling about issued notes, duplicated notes, is that pupils don't read them anyway. To me the important thing is the thinking process they go through to achieve, whether it is an individual thinking process or one in which the whole class takes part when you discuss it with them you might say, 'what exactly are the conclusions for this experiment?', and work at something together and you add two or three clauses, verbally you know; some of them will say, 'aye yes sir, you know, that does not quite work', that is a general conclusion but is a very important process.

Q. Now, supposing a group of average certificate pupils at this school took no notes at all, had no record right through years three, four and five, in physics, no written record but clearly they would still have access to text books and so on - how do you think they would get on?

A. In examinations? (Yes). Well, they wouldn't have very much chance because they wouldn't have gone through these processes I am thinking of, they might know quite a bit about physics. On the other hand, if they were conscientious and working hard why did they not take notes because that is part of science, part of physics, it is a non question.

Q. Turning to more general things, there is this talk about pupil freedom and general sort of liberty and general democracy, deschooling and so on. Just to try and get your view on this, do you think at the present time pupils get too much, or too little, or just about the right amount in this school of personal freedom, you know, what one normally means by freedom?

A. I am not terribly aware of any situation in which I would say the pupils did not have enough freedom. I think they probably have; one has to strike a balance between treating the pupils as individuals and treating them as relatively immature individuals. You can't expect a child, and a lot of these pupils are children, to behave with the same sense of responsibility, therefore you shouldn't put him in a situation where he has to make the kind of decisions, that are difficult enough for a mature adult to make. I think this is certainly true. On the other hand if you give him.... this is a difficult thing, knowing how much responsibility and how much freedom to give them, as much as possible, so that they do grow up into human beings, thinking human beings with a moral sense of their own and yet, on the other hand, don't land the kids with too much responsibility or you make them adults before their time and sometimes turn them into adults in a shock process.

Q. To be a little more specific now about what we mean by freedom, what about freedom to select, you know,

curriculum, subjects that interest them; they don't really have this. In almost every school throughout the country they have to study English for example, they have to study maths up to some stage or other. What do you think of the idea that they should have complete freedom to select only the subjects that they want?

A. Again.. very often a pupil comes back to you in sixth year and says, 'I wish I had known more about what I would need in life, I wish I had known more about what I was going to take at school and I would have made a different decision at the end of second year.' It is difficult enough for the pupils to take decisions with the guidance they are given and guidance is pretty good on the whole; very few pupils have an axe to grind, at least I hope not. I don't think they have, there are very few professional teachers that have an axe to grind in this respect. Selecting your own curriculum, well, I think it is wise for instance for a pupil to be advised always to take English and I can't really conceive of a situation in which a pupil would be better off not doing it, and I'm a relatively mature person who has gone through the academic mill, if you like, through the factory, and reasonably aware of all the implications of a fixed curriculum, of shoving things down people's throats, and turning them into a certain kind of human being, of processing them in our society, at the same time, knowing all these things I still think I can make a better decision in general terms than the pupil

can, therefore I make this decision, advise them of it and I think it works.

Q. Obviously, I think you will agree that what you are saying is that really the amount of freedom they have at the moment is about right and that they should not really have freedom to select their own curriculum.

A. I think it is difficult enough for an adult to make that decision.

Q. Some people are saying it should go further than that, that they should have freedom almost to draw up their own syllabus; in other words, for example, if they quite like doing electricity but they don't care much for mechanics, then they only attend the classes in physics when they are doing electricity.

A. But life is not like that, you know, you can't just do the things you want to do in life. There is the rough and there is the smooth, it is even a part of a discipline of life learning to take the rough with the smooth. Entirely apart from that, if I as a person who has gone into physics at some depth decide that in order to appreciate physics then a knowledge of electricity is necessary, as well as some kind of knowledge of mechanics, then I will expect them to appreciate that I have made that decision, and further, certainly I won't make an arbitrary decision and say, 'you will do that', I would try to show them why I did it. Why I made that decision, but at the same time, you know, pupils aren't adults, you masn't treat them as being adults, it is

unfair to the pupils.

Q. How would you react then in general to the idea that pupils taking physics only study parts that interest them, how would you react to that?

A. I wouldn't like it at all.

Q. Well tell me then... the old question, the general order and discipline in the school and in the class room, what kind of common pupil behaviour do you find most irritating in your own physics class? - Just little things?

A. An unwillingness to respond to all the stimulus you throw at them; this I find, a general sort of 'I am not bothered', a general lazy attitude. I go to a lot of trouble to make things interesting for them and this unwillingness to try I find most frustrating. Pupils sitting chatting in class. I did the same at their age fair enough, and if that's going on you just have to try and silence it by whatever means are most convenient to you at the time and the most effective; but at the same time it doesn't bother me terribly much, pupils are pupils; I find with a general informal level of discipline in the classroom the pupils from the most able to the least able respond reasonably well to this kind of thing. If there is a trouble maker in the class generally, what I try to do is just to laugh at him, avoid a conflict situation, even do it publically if you like, someone is responding in a lazy fashion so I just laugh at them and the rest of

the class usually end up laughing too. Not make fun of them, just...

Q. What sanctions do you take against pupils, if any, who don't do homework?

A. Withdrawal of favour, is the first one. One can be pretty effective in saying some quite nasty things to them but that would be a last resort. I try to persuade in them in the first case that it is necessary and to see why it is necessary. I have used the belt about twice since coming to the school and neither time was it a classroom situation; one was when a boy was brutally bullying another boy.. I forget the other one, it doesn't matter... but I wouldn't think of doing that.

Q. Well, what do you think in general of the use of corporal punishment, what effect, do you think it has any effect on the pupil teacher relations in the long term?

A. It depends on how you use it. I don't think me using the belt a couple of times has any effect upon my pupil teacher relationship. I think the children expect to be belted for that kind of thing. How much is achieved... is a greater subject. If I were to go into a class and start laying about with the belt, definitely the children would regard me as a different sort of person that they regard me at the moment; I like a very informal relationship with the pupils. There is not such a great age difference, there is, one would think, a vast experience difference.

There is not such a big age difference between the pupils and myself and I wouldn't like... apart from the principle of not liking to actually physically hit them it definitely would affect, if you used it to any measurable extent, it would affect a pupil teacher relationship if you started using the belt.

Q. Do you think there is too much, would you say just in general there is too much corporal punishment used in Scottish schools? I know that it is difficult for one to know this, you only get an impression.

A. There is the odd teacher who does use it far too much but it is generally a sign of failure when the belt is used to that extent. Scottish schools in general - I haven't experience really to say.

Q. Fair enough. The last question is, what would, again to bring it to particularise it to your own situation, what would be the effect on you as a physics teacher on your job and your working conditions, if you like, if the use of corporal punishment was prohibited completely, your power to use corporal punishment was withdrawn completely?

A. Well, I don't have a belt. In my teaching life I have used it very very seldom, I can't see it would affect me very much at all. In fact I can't see that at all. The question of whether the pupils would have a different attitude towards teachers, I would have to think about it. One would hope that the thought 'he is going to hit me with a belt', doesn't come into their minds

terribly often. On the other hand there are schools which have reached a level, their teachers have reached a level that to take the strap from them it would be quite serious on their teaching situation. I wouldn't like to make a general decision on this. Certainly, I suppose I am lucky; I have a fortunate relationship with the pupils. I think this is an objective statement. I have a reasonably good relationship with the pupils, I am lucky. I don't think it would affect me either way.

Q. But it might perhaps affect other people.

A. I think it probably might.

TEACHER J - THE TEACHER RATED MOST EXPOSITORY

Q. The thing that often strikes me, going round the schools as I do, you know, is the tremendous amount of noise there is in a science class nowadays, noise and chaos and pupil movement and things like this; do you think the pupils are... to what extent are the pupils learning under these conditions, when there is a lot of noise?

A. In some cases I am quite sure that... the noise is unavoidable and whether the pupil is learning or not depends a lot on the type of pupil; in some cases they can work away quite well, make a fair amount of noise but they are still working quite well; in other cases they make a noise for the sake of making a noise and they are learning nothing. It really depends on the type of class you are working with. This lot we are examining at the moment, they are to my mind a very noisy lot and in some cases I am quite sure some of them are not learning very much, but it is a fairly big section and even though they are not making a lot of noise individually, collectively it becomes quite loud. I have another section, much quieter - I wouldn't say they are much better workers, then again I have a much poorer section who are quieter. So they are a kind of middle section and I feel that if you are too tight with them they would tend to become taciturn, they wouldn't reply at all, whereas if you let them go a bit you are likely to get something from

them.

Q. Certainly one way in which you can cut down the general noise level, assuming that one wanted to do it, is to reduce the amount of pupil experimentation, this is surely where most of the noise.....

A. But I think that would be defeating the whole purpose of science teaching. Half of science teaching, I think, is in experimentation and if you wanted to cut the noise down, if that was your main purpose, I think then demonstration would be the answer because you can control the class much more. I am not so convinced that noise in itself is a big drawback, providing it is not annoying anybody else outside and provided that there is a level of work going on. Sometimes you will get better, sometimes you will get less.

Q. They are probably learning, I think, under these conditions.

A. I think so. I am not so sure it is the ideal situation but when boys in particular get to that age, even a little noise from a boy at that age has quite a volume and collectively it becomes quite a lot and I think you have got to make up your mind that there is going to be a certain amount.

Q. Some of these pupil experiments...? Some of the ones you do in the Third or Fourth Year for example, you know this thing with the gas laws where we use medical syringes, this I suppose has certain advantages, has it?

A. Which one were you thinking....

Q. you know they use these medical syringes, it makes it a pupil experiment too.

A. ... I feel sometimes there that the standard experiments are possibly easier and I feel that you can't let the children do everything, you have got to draw the line at some experiments, for the sake of speed have got to be demonstrations and I don't think you should do experiments just for the sake of doing experiments. I like to give them plenty to do, but on the other hand I feel if I let them do too much, then the work suffers and we get behind and coming towards the end of the fourth year you are pushing it to get the course covered. I think you have to strike a happy balance where you let them do a fair amount of useful things. I wouldn't say you would let them do things just for the sake that they have got to do something. I feel that some experiments are better done by the teacher.

Q. Yes, you have made your point. Now another thing, this specific latent heat of fusion of ice, this is the one with the filter funnel and the ice cubes and the heaters.... that makes it a pupil experiment, doesn't it?

A. Well, I have never considered that one as a pupil experiment. I have always done that one as a demonstration. I feel they do their specific heat capacities, they do their cooling curves, they do their gas laws, not Boyle's Law, they do Boyle's law collectively, but they do Charles law individually.

They do a fair amount of work on heat individually and then I usually do the latent heat experiments as a demonstration.

Q. On the whole would you say that pupils learn best by doing experiments themselves or by watching demonstrations?

A. Actually I think they learn more from a demonstration than they do... some pupils on the other hand learn quite a lot by doing the experiment, but it is quite often you will find, especially if they are working in pairs there is a strong member in the team and a weak member and the strong member does most of the work and the weak one just follows on and I sometimes doubt very much whether he is getting a great deal from it; the strong one is the one who is on top of his work, is really learning to handle the apparatus if nothing else, whereas the other one is learning to take orders because the other one directs him.

Q. Yes... that might be his future role... looking at the aspects of learning physics, you know, by doing or whether it is better to watch and I think we have discussed that. Now people sometimes say, and I certainly would like to hear your views on this, people sometimes say that pupils learn, you know, educationists say, when they are enjoying it they are learning best. I don't know if you would agree with this or not?

A. Certainly if they can enjoy everything they do it would be a great life; but it is a discipline and they have to discipline themselves, consequently you would

never expect life to be all a bed of roses, there must be periods when it is hard work, and whether you enjoy it or not is beside the point. It has to be done. I feel there are many things you can make enjoyable, other things you would find it very difficult.

Q. What kind of lessons in physics do you find that pupils do enjoy most or dislike least?

A. Well, I think pupils are so varied in character that what pleases one doesn't altogether please the other; for instance take your objective question book, I find the kids love that, they never seem to get tired and I would have thought that after doing them for a while they might have got a bit fed up and want to do something else, but no they seem to enjoy it. On the other hand, I have found pupils who are not at all keen to do experiments. They are quite willing to sit and listen to me.

Q. This takes us back to the previous point. How can one tell, this often bothers me, how does one actually tell whether they are enjoying it or not, how can you tell something like this?

A. This is a difficult thing as again it depends on the pupil himself. You find that pupils come up at the end of the lesson and ask about something and obviously they are interested in it... very often you get pupils who are exuberant and always on their toes in the class and I am quite sure when they go out of the classroom there is not a thought in their heads

about physics. So it really is a thing that is very difficult to discern.

Q. Sometimes pupils enjoy exploring a side issue, this is supposed to be an important thing. It never used to happen very often to me but it may have happened to you; do you find this happens often?

A. Well, quite frankly no because I don't let it happen. I think that our Third and Fourth Year schemes are fairly tight and if you want to be sidetracked in some way then you have got to put in extra time. I don't think you really have time in the class. I really find you have plenty to do to cover the course. I agree that sidetracking is quite valuable sometimes if there were no exams to do at the end or if there was plenty of time then it could be done.

Q. The next question is... you might well say, you should not need to ask a question like this... surely you should know the answer, you have been here often enough... but if you were asked to tell somebody, say you were to go to a college of education and talk to some students, how do you generally start off a lesson to a Third Year physics class, apart from saying 'come on, sit down'... once you have got the formalities over, what would you say that you normally do? Do you need to think about this?

A. No, I really don't need to think about it. I am quite sure. I do various things depending on the class. If it is a good class, a few minutes to get

the trend from last week.

Q. How do you do this then?

A. I usually break the ice by broaching the subject and then just make sure they are with me by asking a few questions. I normally do that with most classes and again it depends on the pressure..... from there, of course, we talk about the work in hand for the day, what has to be done and I try very hard to make sure everybody understands what they are trying to do before we start it. Sometimes it is not always...

Q. What would you say would be the best way of doing that?

A. It all depends on what you are trying to do; if you are trying to find a constant for instance there is no bones about it, we are going to try and find a value for this constant. If, on the other hand, we are going to do a bit of deductive work then sometimes you can approach the subject by saying, 'suppose we do such and such a thing, what possibilities do we have of what might happen?', and asking questions, without giving the answers, then let us try the experiment and find out which is true sometimes, but again, it is a thing you would decide from what has to be done.

Q. This business of asking questions, certainly if one has the time, always, I suppose, people usually say this is what you ought to do, don't they?

A. I feel that to start a lesson without knowing yourself that they are in a position to be able to do

the lesson, is wrong, you've got to know they have enough background knowledge to be able to perform the experiment.

Q. So if you could, could you summarise, as I was saying, how would you summarise your attitude to the general sort of idea of asking questions in class, maybe you've answered that question already?

A. Oh, I feel you should ask questions but not always expect an answer. You should ask questions sometimes to promote thought. You should ask questions sometimes to find out if the class have sufficient background knowledge; you should sometimes just ask questions for the sake of asking questions to find out if they have been doing any work.

Q. Yes, indeed. We are really, of course, discussing all sorts of factors that relate to the way that a teacher does his job and these days people are always saying, especially people that are outside schools, 'now the teacher ought to have aims and he ought to have an aim.' 'He ought to know what he's planning to do before he starts his lesson' and so on. Take, for example, Boyle's law, you know the setting out to do Boyle's law. I mean if you were going to sort of write down, obviously a very experienced teacher wouldn't do this, but supposing you were showing a young teacher how to go about this. You said, 'Right, you go and write down what you think Boyle's law - you know, what your aim ought to be for yourself', not the things they

write in their books but what he ought to have in his own mind. He set down the form of words like 'To prove to the class that the pressure of a fixed mass of gas at constant temperature is inversely proportional to the volume', and he said, 'well, that's my intention, that's what I'm going into that classroom... to do.' What would you think about this, what would you say about that?

A. Well, I really think that's the wrong way to go about it altogether. I think the ground would be half prepared possibly by doing the pressure law first; I think that's how we normally start it and during that experiment I'm sure the question must arise, 'suppose we then keep the pressure constant what must happen to volume as pressure changes?' and I think without actually proving a law we would get the general idea first of all by experiment, having decided that there are possibilities, what might happen to the volume if the pressure changes. You'll always get plenty of suggestions and therefore you do the experiment to find out but it would only be at the very end that I would dream of bringing in this idea of a formal statement.

Q. A formal statement, yes?

A. There are so many things in the formal statement of the law, so many important things that I don't think it's a thing you throw at them, you've got to digest it very thoroughly before you formally state it.

Q. Yes?

A. Well it's a fixed mass to start off with; it's

quite an important thing and it needs a fair bit of.. and the inverse proportion, well, if course, I feel that right from the word go, in science and physics particularly, we are dealing with proportions so when we finally come to do Boyle's law the proportion part shouldn't be very difficult. They should have had examples of that before so that shouldn't need very much.. Oh I think that in general terms, volume increasing, even the old diagram you know, the Z thing, this to me is as important as the formal statement of the law, until everything is tied up, then we can quote the law in its formal form.

Q. Right. Well, now supposing you are giving out apparatus for a pupil experiment; let's say it was a Third Year class and it was the first time they had actually used these ticker-timers but they've maybe used the trolleys before. So you are giving them out the ticker-timer experiment, either with trolleys or without trolleys depending on how one does it. What would you reckon would be the aim of this lesson; in other words what would you expect your pupils to do inside a couple of periods?

A. With ticker-timers?

Q. Yes.

A. Initial treatment. I would say there was a snag here because I always approach this, we do a bit of timing, you know, different methods of timing early on so by the time they actually come to use the ticker-

timer they have discussed these different methods of timing, they probably know what a ticker-timer does and possibly have had a demonstration on how to use it.

Q. Well, but the first time they use it for timing, what would you expect them to do with it?

A. Possibly make a tape, say walking, pulling it with the hand is the standard one I think, examining the tape.

Q. What instructions would you actually give them, when you have given out the apparatus for this timing lesson and you have given out the actual apparatus, you know the power packs and the ticker-timers and the paper and so on. What instructions would you give them as to what to do?

A. The voltage required, have a word about that, not to exceed it, not to leave the ticker-timer running when it's not actually printing on the tape; I don't think there's very much more, you know, you could ask them to do...

Q. What would you tell them to do, you know what... tell them to make a tape, or make a number of tapes, would you explain in any sort of detail what the various parts were?

A. They would have done that, of course, they actually do that in the second year, they do it in second year, section 11, they do a bit with vibrations...

Q. So they meet the ticker-timers...

A. Well, they actually meet this idea of the vibrator in the second year and they do a bit about the pitch of a note and from the frequency the length of the

vibrating strip. I don't think I deal a great deal with the a.c. effect of the thing, apart from mentioning that it is a.c. that we use but in actual fact they see that as well, in the second year in section 15. So it is possible to tie all these ends up by recalling, not that we recall a great deal from second year, but that comes towards the end of the second year, and you will be doing waves early in the third year, you will be doing frequency and amplitude and things like that. So you could possibly tie it up quite neatly. I really haven't given a great deal of thought to this idea of explaining the... actually by the time we reach the ticker-timer I think we are pretty well organised and they know what they are doing.

Q. Suppose when you gave out this apparatus for the first time, actually the first time they have used it themselves and you simply tell them, 'here is a bit of physics equipment and I want you to use it to find out, make some kind of measurement in physics', and that is all you told them. What would you expect them to achieve inside a double period? What would they do...?

A. Without giving them any help...

Q. Just give them the necessary equipment?

A. I don't think they would get a great deal out of it. I don't think very many of them would realise the frequency of the mains or would they?... I am trying to think would they be able to tie that in to get their

actual time intervals. They possibly would realise that the time intervals was constant but whether it was a 50th of a second, I doubt very much if they would jump to that.. I would not like to say what we'd get out of that one.

Q. A question on homework now. Do you think the pupil's attitude to the subject is affected by homework, you know, is the pupil's attitude to physics determined by the amount of homework he gets or whether he gets homework?

A. I think to some extent it is. I feel that if they get no homework they tend to treat the subject far too easily, they think it is all too easy. I think homework is a necessary part of learning. In modern times where there is so many distractions it is even more important than it used to be.

Q. Some teachers... I was talking about this recently to one who gives all his classes regular ink exercises right the way through, one a week, and they have to hand it in neat and all this; on the other hand there is another chap I was talking to; he reckons that homework is just an evil imposition, an anti-social thing that you should not do to these children, they should be out enjoying themselves... where do you stand on this?

A. I think I would fall half-way between. I don't think a regular ink exercise has any great value unless, of course, it is properly marked and examined thereafter. The giving of a home exercise just for the sake of

giving it, to make sure that they are going some work to me is valueless, unless you can really follow up that home exercise, to me it has not a great deal of value. Home Exercises is not the only homework they are asked to do. You can ask them to do other things which are sometimes more important than being able to write out something neatly; certainly that's part of the game but that can be done in the class I feel. Being neat and tidy can be started fairly early on and encouraged throughout but I can't say I'm a great believer in a weekly home exercise and one of the main reasons of course is that quite frankly I couldn't discipline myself to do justice to it.

Q. What other kind of homework then do you think would be useful?

A. Sometimes even a small project is of value where they've got to look up text books for various things; just mention a word for instance, just sometimes... take for instance, radar, just mention the word radar. By the time they do it in the Third Year of course they have a fair idea but ask them to get some concrete facts on radar, sometimes it's quite a valuable piece of homework which you don't necessarily need to make an imposition. Everybody hasn't to do it. Those who are keen enough to do it, will do it. But homework for the sake of doing homework I think is of no great value.

Q. Yes. Talking about motivation and what makes them tick, I think the subject of examinations is one of the

big things that people sometimes claim in this respect but I suppose the main purpose in examinations is meant to be of some kind of measure of ability. Would you say, in your view, that physics exams are a measure of ability?

A. I think I'd agree, I suppose. I don't think they measure everything about a pupil, they certainly don't measure everything about a pupil, a written exam doesn't measure his dexterity with apparatus for instance but unless you bring in a practical exam which we threw out a long time ago, what are we going to do. But you often feel that if someone is to go far in a subject they must master it theoretically if nothing else and consequently the only thing you can do to find out this is to examine them theoretically.

Q. So if you did away with examinations what result do you think this would have, what effect would this have?

A. Oh, I think a lot of people would be happy, but I don't think we would... well we'd have to substitute some other method of testing.

Q. Why is that? Why would you feel this?

A. Because life's a rat race.

Q. Yes. Suppose we weren't so sweeping in our doing away with exams but instead we just did away with this pass/fail, you know they've already done that a bit in the fringes, in the Sixth Year Studies for example where they all get a different grade. What would you think of that?

A. I really don't think it's worthwhile because anybody who is in the know to any extent knows that a low band is virtually a fail, so you're just disguising it from the people who aren't even interested in the thing, and to those who are interested and therefore know that our low band in the Sixth Year Studies is virtually a fail.

Q. That's right.

A. So you're not really gaining anything, for instance, employers must be sure, be aware that a low grade in the Sixth Year Studies, universities certainly know it; there's no doubt about that; training colleges know it so who are we trying to fool when we say A, B, C, D, E, I really can't see the point in it... even the pupil knows it and in itself that is the final thing I would say.

Q. Well, what would you consider then to be the most likely effect on you personally, coming back to your own situation - to you personally as a physics teacher, you know your job here in school, if all exams, internal, external, S.C.E. the lot were done away with; how would it affect your job?

A. Well, quite frankly I think that either unconsciously or sub-consciously there would be an easing off in the level of my work. I really think so. Because there's no doubt about it in my mind that if there's an aim for the pupils you really set out to make sure they achieve it. I really feel that if there were no exams we'd probably have a lot of fun, we'd probably learn an awful lot of physics but you would really

never know those who had learned a lot of physics.

Q. Who had learned what...

A. Yes. That's it.

Q. Yes. Now, to be more specific and ask sort of particular questions of fact rather than an opinion about note-taking. What do you say to Third Year pupils who have done a pupil experiment, what records do they have of this in your case?

A. Well, sheets that I've prepared for them usually...

Q. This is work sheets?

A. Work sheets, yes. I use work sheets and the main reason, or the two main reasons I find that if you don't have work sheets you really must supervise what they are writing and if you don't get the time to do it then, quite frankly, I don't think the kids get an awful lot out of it because they can't. You've got to train them.. in the old days we more or less dictated it. We put it on the board for a while then eventually by the time they reached the Fourth and Fifth Years they were doing their own. Nowadays I think that to cover the work you've got to issue work sheets of some form. You don't write everything, you certainly leave enough for them to fill in bits and pieces, sometimes only a few words, sometimes a couple of sentences, certainly the results, I think, you either have to go over on the board and they then copy them down or you've got to spend an awful lot of time at the beginning making sure that they will be able to take the correct results and for

speed I have definitely gone over to the idea that you print notes with plenty that they can do themselves to fill in but the beauty is that when they've done it they have a record which is to your mind almost 100%. Mind you that gets us back to the idea, is physics teaching the ability to make them read up notes so that they always know the right answer. But then again that's a different part but it's certainly part of the work because I think there's nothing gives a pupil confidence so much as the fact that he can take a book and know that he's going to read something and know that it's right, whereas if you take your own homemade notes, the pupils' own notes, sometimes after six months you can't make head nor tail of it.

Q. Do the pupils ever at any time compile their own notes?

A. No, not really; I feel that I never have a great deal of time at the end of the Fourth Year. I probably do more experimental work than a lot of schools. I tend to say that from what I hear from other people and not only do I do more experimental work with the pupils but I also make the course a bit fuller than some of the other people do and constantly I find that I'm never well on by the time the exam is... if I have a month at the end to revise I think I am quids in, very seldom do I ... a fortnight's revision, we just finish off the course, a fortnight's revision and sometimes I feel that

I should knock things out. And then I try to look at the thing as a whole and I feel that if I miss that out I feel that I am breaking the thread sort of style you know. There are so many things that we have knocked out already and I feel that, well for instance, Jardine's new Nat. Phil. books... you haven't seen these? Well to me I think it's only half a course.

Q. I see. Oh the work books?

A. Yes.

Q. Oh. I've seen these, yes I have seen these. I thought you meant the new...

A. No. The work books. I feel that if that's all the kids are doing, I feel that I would like to do a bit more whether he was intending that these are things that the pupil should do and the teacher should do other things, I'm not so sure. But I know that a lot of schools are doing nothing else but using these books. Another point about the notes is that I have found by experience that young teachers in particular who are doing the thing for the first year are absolutely lost and not only are they absolutely lost they are not prepared to sit down and make out a scheme for themselves. I know it. I mean you can't really teach a thing until you've really thought it all the way through. And it would be a good thing to say to a young teacher who's taking for instance a Third Year wave section for the first time 'make up your own notes.' It would be great. But I've seen some of the efforts and I feel that it's better my

way, do mine; I would never object to them doing more but at least I like to know that they are doing what I suggested. I feel that they are getting a fairly full course if they are doing that. If they want to do more, if there's time to do more, sure thing. And I'm always willing for them to suggest that they might do this.

Q. Now supposing a group of, you know, average pupils in the school here took no notes at all during the physics lessons for years 3, 4 and 5, you know average 'Higher' pupils, not the few really good ones, not the few that really shouldn't take the course, but the average group; suppose that they never took any notes at all; you know, you said, well, we'll just do this and see how it works out. But they've actually got no permanent records, they just took down their experimental results on small bits of papers and threw them away at the end. How do you think they would do?

A. Terrible. I really do. I mean I can see when we're revising at the end of the session you come across a point, perhaps only a month since you've done it, and you don't recognise it. The answer is no. I can say, turn to page so-and-so, I can quote the page you know and see what we've got there. And then, of course, whenever they see it, oh of course, it comes back. But I feel that unless they have something there to look back to, oh no, I really don't think they would be able to cope.

Q. Yes. Now there's another thing that's very much

on the go at the moment and we're going to have to cope with this somehow or another; I think in the future, all this pupil freedom and de-schooling and all this stuff. How much freedom... are the pupils resenting discipline and so on. How much freedom do you think pupils should have, you know, in secondary school, I mean do you think they have, say in this school, do they have enough of it, or too much or too little, or what? Pupils in school, secondary schools generally.

A. Oh, quite frankly I think the discipline problem is becoming terrible. I really do because I think they are becoming barrack room lawyers. They know their rights nowadays and some of them play to them.

Q. So, do you think they've got too much freedom already, you know by freedom I mean sort of personal freedom, personal freedom in the normal way that we mean this... to come and go?

A. Well, in this school it's rather peculiar because we've just been having meetings about this idea about discipline and personal freedom, personal code for the teachers and for the pupils and quite frankly there are one or two pupils in this school who are really going to town at the moment and we are having a bit of a job with them and the unfortunate thing is that we can't catch them you see. They never come out in the open, they do the things behind you back sort of style. Some of the younger staff are having a thin time of it and quite frankly until we get an ultimate deterrent we

are really going to be in trouble I think in the next few years.

Q. Yes. So supposing you gave the pupils, all the pupils, not just a few of them, what about the idea of giving them freedom to select subjects that... just to do the subjects at school that interest them; you know at the moment they have to generally do English and Maths...

A. This would be alright, provided that universities did not require certain things. You see this is it, we often have, not only amongst pupils, amongst the staff, sometimes the staff give them wrong advice, you know?

Q. Yes.

A. And then they come a year later and say I should have taken this for my course and we are trying to avoid this, of course. This has happened in the past and next year for ROSLA we are offering options for the ROSLA pupils, which is an innovation and we don't know how...

Q. Now, within that, you know, if you are maybe going to give them some freedom to select objects that interest them, what about within each subject. What do you think of the idea that they should only attend the classes and topics that interest them, which in a way means letting the pupils make up the syllabus... how do you react to the idea that the pupils taking physics for example study only the physics that interest them, they quite like electricity but they can't stand mechanics, so they don't come to mechanics.

A. This would be fine provided the pupils did not need to know mechanics and it would also be fine provided there also was an alternative place for them to go if they weren't studying mechanics. I think it would be a bit of disorganised chaos; I think, in fact, if they could just go from here to there you would never know where they were. The checking up that they are somewhere would be quite difficult.

Q. Well, related to that, there is this question of general sort of order and discipline. We have been talking about this already but to be more particular about it, in the room here in physics, what kind of common pupil behaviour do you find most irritating of all the various forms of pupil behaviour that one finds irritating?

A. There are one or two - dumb insolence, it doesn't worry me too much because I think you are going to get that sometime or other and... the one that really annoys me is the pupil who is coming to the school just because he is being forced to come to the school - he is not going to do any work no matter what you do and he is wasting his time and he is wasting your time and I would say that is the one that I really hate most and it becomes very obvious, I think, Other things, normal classroom behaviour, well it is your own fault if things like that annoy you. The result is you to blame if these things are happening...

Q. What sort of classroom behaviour do you find irritates you?

A. Classroom...

Q. You know, just little things? It used to be the talk about football that used to drive me up the wall. They should be doing an experiment and they would be talking about football...

A. No, we don't get an awful lot of that ...naturally shouting out annoys you...

Q. You mean shouting out in answering, instead of...

A. Well there again it depends on the year or the classes, the age, at the First Year you expect them to stick their hands up before they answer but again it depends on the class, but even some First Year classes you can organise, that you can talk to them and somebody will give you an answer, without the raised hand up and you can take it, in other classes you have half a dozen speaking, shouting out answers, you have the class where everyone puts their hands up and snaps, you know, a relic from the primary school... these things you eventually sort out...

Q. Do you take any sanctions against pupils that don't do homework?

A. No.

Q. What do you think then of the use of corporal punishment, I know one could go on about this for ages, well, to be more specific, what effect to you think it has, if any, on pupil teacher relations?

A. Well... one of my best friends, ex-pupil, I belted him right, now that was an isolated case. We really fell out and I really went to town on him. Not in temper, I must admit, I don't lose the temper very easily and especially I don't lose the temper when I am belting somebody. It was such that he had to be punished and he was really punished that one but he is one of the nicest boys to me thereafter. On the other hand some pupils you could belt all day and it wouldn't make the slightest bit of difference, so corporal punishment is like every other form of punishment, it depends on the pupil. You couldn't lay down a rule for any situation, I don't think. You have got to be a psychologist, there is no doubt about it and whereas one of the belt at the right time would sort everything out the use of the belt at the wrong time would do nothing, it would make the thing worse.

Q. Do you think there is too much corporal punishment used in the schools?

A. On the whole, yes, I would say so, on the whole. I think they use the strap for things, well, that I wouldn't use it for.

Q. Such as...

A. For instance, homework, I certainly would not use it for homework. If I find a child is not doing his homework then I have a few words to say to him, why shouldn't he do his homework, and if he gives me a reasonable answer then it is on his head.

Q. Well, the last question, what would you consider to be the likely effect on you, as a physics teacher, as a teacher in school, if the use of corporal punishment in the school, your authority to use corporal punishment was completely withdrawn, as they have threatened to do?

A. If it was withdrawn without some other deterrent I think life would be intolerable absolutely because there are enough barrack room boys around now that could make your life pure hell. I really think that. There are only a few but it would spoil the whole place unless there is something that could be done, then I would say that the strap must stay... but if you could get something worthwhile, as they do in some other continental countries, for instance where the parent suffers if the child steps out of line, then I think something could be done along that line but to take the strap away without putting something in its place, something concrete that really could work, I think would be a bad step.

APPENDIX III

**INSTRUCTIONS TO EXPERTS CONCERNING
RANKING OF INTERVIEW TRANSCRIPTS.**



DEPARTMENT OF NATURAL PHILOSOPHY
THE UNIVERSITY
DRUMMOND STREET
EDINBURGH.
EH8 9UA

Dear

Thank you for agreeing to help with my research. For each of the eleven topics you should attempt to place the six transcripts in rank order according to the strength of agreement or otherwise they seem to reflect with each of the specified statements. Where it seems to you that the interviewer has loaded the questions more in one transcript than in others you should take account of this in ranking the teacher's response.

Please check very carefully to ensure that the transcript ranked '1' is that which represents greatest agreement and that ranked '6' represents least agreement and that you have not inadvertently reversed them. The order in which the codes appear in each Topic sheet has no significance: the first transcript quoted in each topic does not represent the same teacher.

Please do not write anything on the interview transcript.

Very many thanks,

James G. Houston.

APPENDIX IV

ATTAINMENT TEST I.

ATTAINMENT TEST I

Take g to be 10 m/s^2

Time—One hour

Instructions to the candidate:

1. All questions are of the same kind. There is only one answer required to each question and there are no trick questions.

2. Each question consists of alternative answers lettered A, B, C, D or E, and your choice should be indicated in **pencil** by a vertical line in the answer sheet provided. **Be very careful to put the vertical line in the correct square.** If you change your mind, erase the line completely. Two replies to one question will result in loss of marks for that question.

3. Mathematical tables and other relevant data are provided.

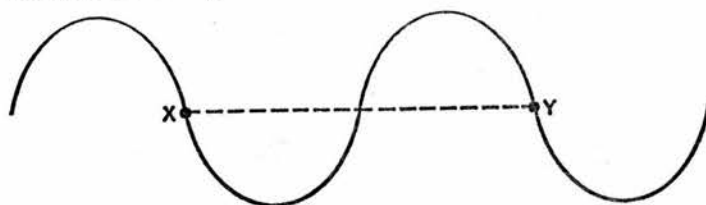
4. All questions should be attempted.

5. Rough working must be done only on the paper provided. Do **not** write on any part of the question paper.

6. Make sure that only **one** of the alternatives is indicated in each case.

7. At the end of the examination, both question paper and answer sheet must be handed in.

1. The sketch shows part of a transverse wave.



The distance XY is called the:—

- A. amplitude.
- B. displacement.
- C. frequency.
- D. velocity.
- E. wavelength.

2. Which waves travel fastest?

- A. water waves.
- B. ultra-sonic waves.
- C. shock waves.
- D. sound waves.
- E. radio waves.

3 . Which waves are longitudinal?

- A Infra-red.
- B Light.
- C Sound.
- D Ultra-violet.
- E X-rays.

4 . Which of the following electromagnetic waves is the most penetrating?

- A. ultra-violet rays.
- B. gamma rays.
- C. infra-red rays.
- D. microwaves.
- E. x-rays.

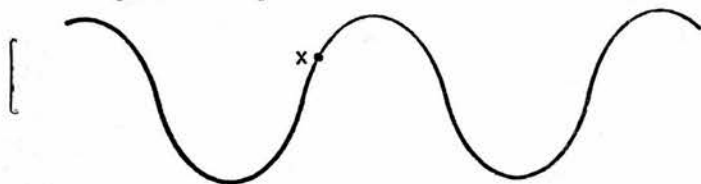
5 . Which waves have the highest frequency?

- A. infra-red.
- B. light.
- C. radio.
- D. ultra-violet.
- E. x-rays.

6 . Which of the following waves has the longest wavelength?

- A. infra-red.
- B. radio.
- C. ultra-violet.
- D. visible light.
- E. x-rays.

7 . The diagram shows part of a transverse wave in a rope.




When the point X is observed for a time it is seen to be:—

A. STATIONARY

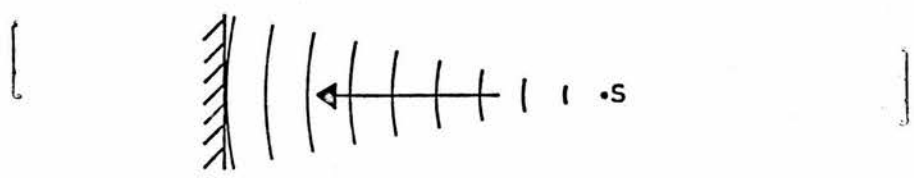
B. MOVING 

C. MOVING 

D. MOVING 

E. MOVING 

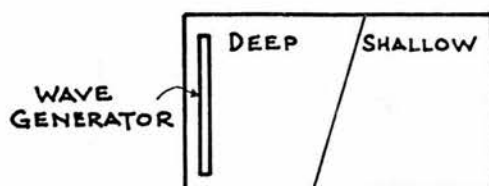
8. In a ripple tank, a source S emits circular waves which are reflected from a straight barrier. The diagram shows part of the incident waves.



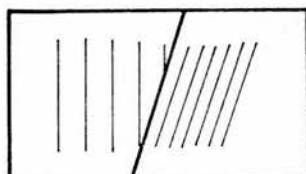
The pattern of reflected waves is:

- (A)
- (B)
- (C)
- (D)
- (E)

9. A piece of glass is submerged in a ripple tank so that the water is deep in one half and shallow in the other as shown below.



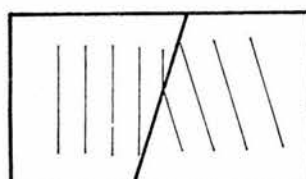
When straight waves are produced by the wave generator the pattern in the tank looks like:—



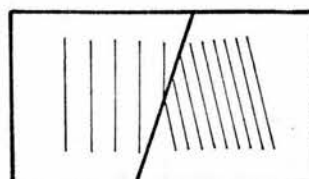
(A)



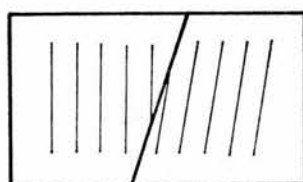
(B)



(C)



(D)



(E)

10. When the pitch of a sound increases, what characteristic of the sound wave increases?

- A. amplitude.
- B. frequency.
- C. speed.
- D. wavelength.
- E. none of these.

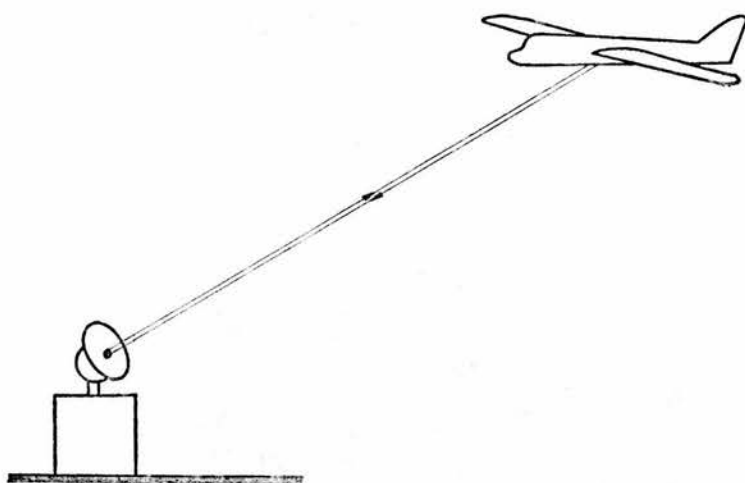
11. A pupil stands 80 m from a large wall, claps his hands and listens for the echo. If he hears the echo 0.5 s after the clap he calculates the velocity of sound to be:—

- A. 40 m/s.
- B. 80 m/s.
- C. 160 m/s.
- D. 320 m/s.
- E. 640 m/s.

12. Waves have a frequency of 50 Hz and wavelength of 10 m.
What is the wave speed?

A 0.2 m/s.
B 0.5 m/s.
C 5 m/s.
D 50 m/s.
E 500 m/s.

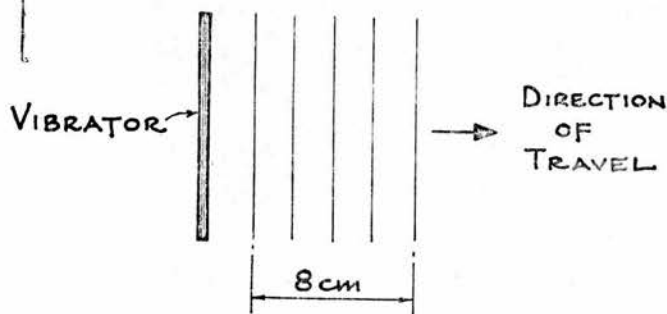
13. A radar pulse, reflected by an aeroplane, returns to the transmitter 2×10^{-4} s after it has been emitted. The speed of radar is 3×10^8 m/s.



The distance from the transmitter to the aeroplane is:

A. 3×10^4 m.
B. 6×10^4 m.
C. 6×10^7 m.
D. 1.5×10^9 m.
E. 1.5×10^{12} m.

14. The diagram shows the crests of waves in a ripple tank being produced at a frequency of 15 Hz.



The velocity of the waves in cm/s is given by:—

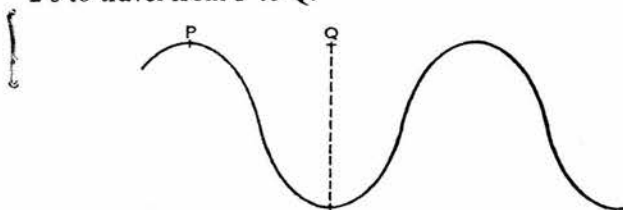
A. $15 \times \frac{8}{4}$
B. $15 \times \frac{4}{8}$
C. 15×8
D. $\frac{1.5}{8}$
E. $\frac{8}{1.5}$

15. Sound can be focused by a balloon filled with carbon dioxide showing that sound:—

A. travels faster in carbon dioxide than in air.
B. travels at the same speed in carbon dioxide as in air.
C. cannot travel through a vacuum.
D. travels slower than light.
E. travels slower in carbon dioxide than in air.

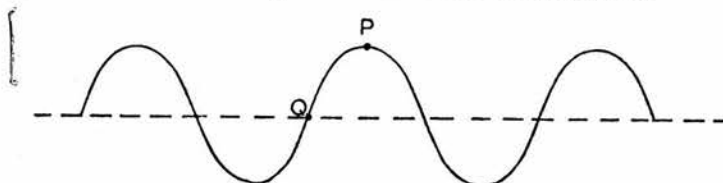
16. When you walk away from a band playing in the park the sound gets fainter, but the tune can still be recognised. This shows that:
- A. high notes travel faster than low notes.
 - B. low notes travel faster than high notes.
 - C. all notes travel at the same speed.
 - D. the high notes interfere destructively.
 - E. the low notes interfere destructively.

17. The diagram shows a wave profile in a rope. It takes a wave crest 2 s to travel from P to Q.



The frequency of the wave motion is:—

- A. $\frac{1}{4}$ Hz.
 - B. $\frac{1}{2}$ Hz.
 - C. 1 Hz.
 - D. 2 Hz.
 - E. 4 Hz.
18. A string is vibrating as shown with a frequency of 6 Hz. The particle P of the string is at its maximum displacement.

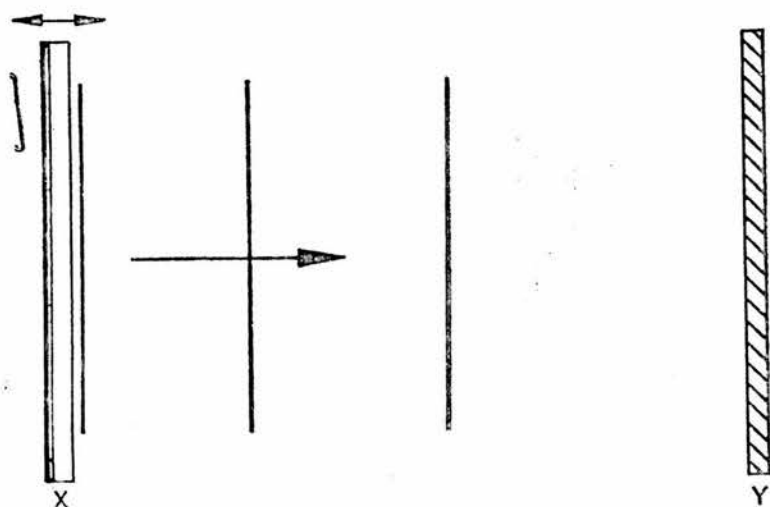


How long will it take for particle Q to reach its maximum displacement?

- A. $\frac{1}{24}$ s.
- B. $\frac{1}{12}$ s.
- C. $\frac{1}{6}$ s.
- D. 6 s.
- E. 12 s.

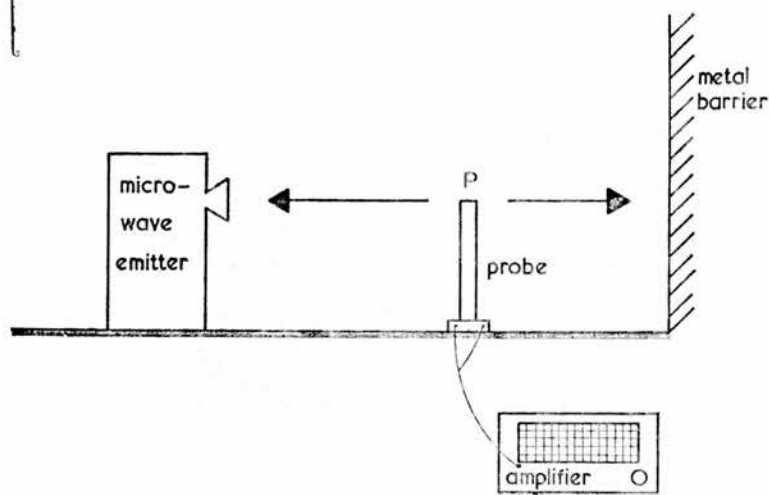
19. In the diagram below X is a vibrator sending out straight waves of wavelength 3 cm and frequency 2 Hz. The reflecting barrier Y is positioned so that standing (stationary) waves are produced.

7



The distance XY is:—

- A. 4 cm.
 - B. 7 cm.
 - C. 8 cm.
 - D. 12 cm.
 - E. 16 cm.
20. Micro-waves of 3 cm wavelength are reflected from a metal barrier. A probe moving between the emitter and the barrier detects the waves. At P, the strength of the signal is a minimum.



How far from P is the probe moved to obtain the next minimum?

- A. 0.75 cm.
- B. 1.5 cm.
- C. 3 cm.
- D. 6 cm.
- E. 12 cm.

21. A scalar quantity has only

- A direction
- B magnitude
- C sense
- D magnitude and direction
- E direction and sense.

22. Force is measured in the unit:

- A. J.
- B. kg.
- C. N.
- D. W.
- E. none of those.

23. A unit of acceleration is:—

- A. m/s
- B. m/s^2
- C. m^2/s
- D. m^2/s^2
- E. m s^2

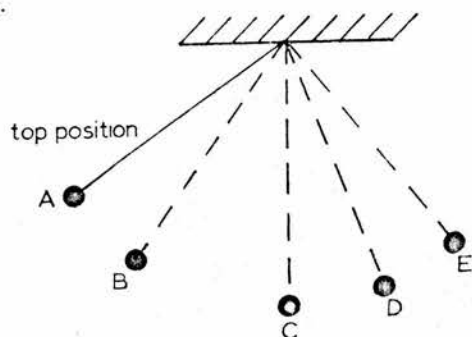
24. In what unit is displacement measured?

- A Metre.
- B Metre/second.
- C Metre/second².
- D Newton.
- E Second.

25. Gravitational field strength has unit

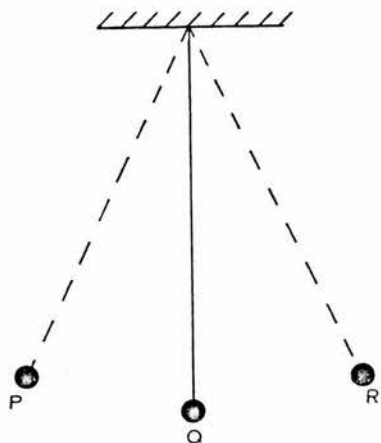
- A N/kg
- B kg/N
- C N m
- D N/m
- E kg/m.

26. The sketch shows the position of a simple pendulum at various points in its swing.



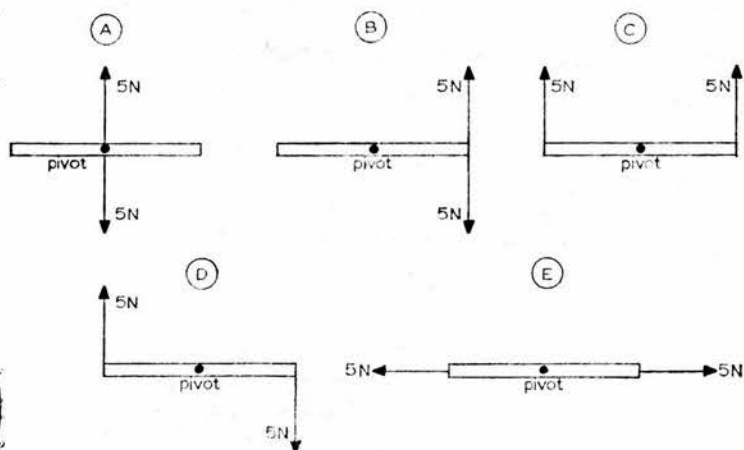
At which point is the kinetic energy of the pendulum greatest?

27. The diagram shows a simple pendulum which swings between P and R. Q is its central position.

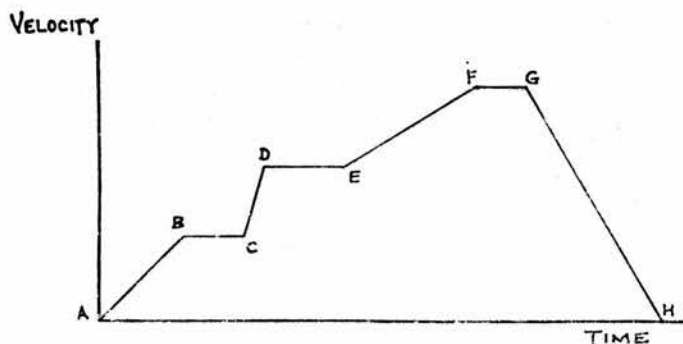


The period of the pendulum is the time taken for it to go from

- A P to Q
 - B Q to R
 - C P to R
 - D P to R and back to Q
 - E P to R and back to P.
28. A uniform rod, pivoted at the centre, is acted upon by two forces in the same plane. In which case is there a turning effect?



29. The diagram shows the velocity-time graph of a car running along a flat straight road.



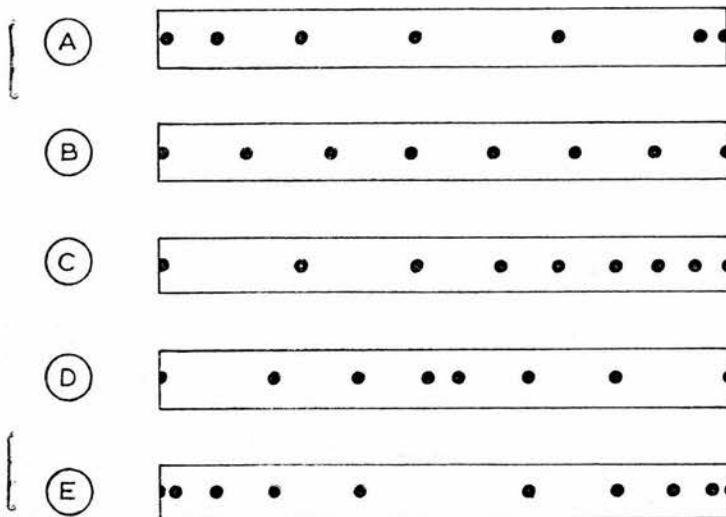
The acceleration of the car is greatest in the region:—

- A. AB
- B. CD
- C. EF
- D. FG
- E. GH

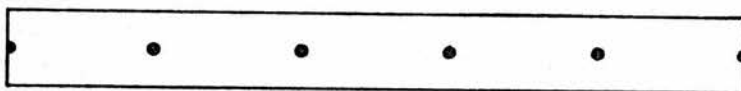
30. The area under a speed-time graph is a measure of:—

- A. acceleration.
- B. distance.
- C. force.
- D. speed.
- E. time.

31. A pupil obtains five sections of ticker tape using the same timer. Consider the full length of each tape and say which section represents the greatest average speed.



32. When a tape is pulled at a constant speed of 2 m/s through a ticker-timer vibrating with a frequency of 50 Hz, 6 dots are produced on the tape.



The length of the tape is:

- A. 0.20 m.
- B. 0.24 m.
- C. 2.0 m.
- D. 6.0 m.
- E. 12 m.

33. What is the force of gravity on a mass of 5 kg?

- A. 0.5 N.
- B. 5 N.
- C. 10 N.
- D. 50 N.
- E. 500 N.

34. A mailbag is weighed on a weighing machine in a train which is stopped at a station. The bag weighs 500 N. When the bag is reweighed while the train is accelerating at 0.1 m/s^2 along a horizontal track the reading on the weighing machine is:—

A. 50 N.
B. 450 N.
C. 500 N.
D. 550 N.
E. 5000 N.

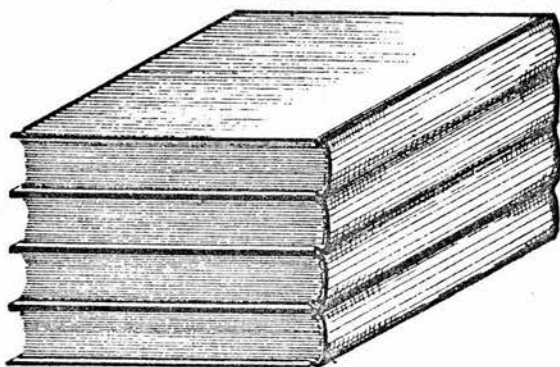
35. A 10 kg mass is suspended as shown from a spring balance. A force of 200 N is exerted on a string attached to the underside of the mass.



What is the reading on the spring balance?

A 100 N.
B 190 N.
C 200 N.
D 210 N.
E 300 N.

36. Four books are piled one on top of the other. Each book weighs 5N.



What force does the bottom book in the pile exert on the book above it?

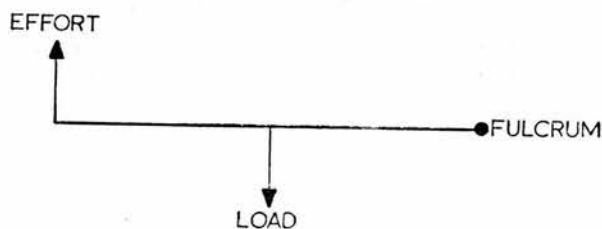
A. zero.
B. 5 N.
C. 10 N.
D. 15 N.
E. 20 N.

37. A ball is falling near the Earth's surface. Where the resistance force exerted by the air on the ball is called the ACTION, the REACTION is the force exerted by the:—
- Earth on the ball.
 - ball on the air.
 - Earth on the air.
 - air on the Earth.
 - ball on the Earth.

38. A metal sphere is released in outer space where the pull of gravity is weaker than on Earth. How does the mass and weight of the sphere compare with its mass and weight on Earth?

	<i>mass</i>	<i>weight</i>
A	same	same
B	less	less
C	same	greater
D	greater	same
E	same	less

39. The diagram below represents a lever.



In its operation which is most like the lever shown?

- Wheelbarrow.
 - Sugar tongs.
 - Pair of scissors.
 - Forearm.
 - Crowbar.
40. A pupil carries out an experiment to find how the acceleration of a body depends on the unbalanced force applied to the body. These are his results.

Which pair of values should be disregarded?

	<i>acceleration</i> m/s^2	<i>force</i> N
A.	0.2	4.0
B.	0.8	9.6
C.	1.0	20.3
D.	1.2	23.7
E.	1.5	30.0

APPENDIX V

ATTAINMENT TEST II.

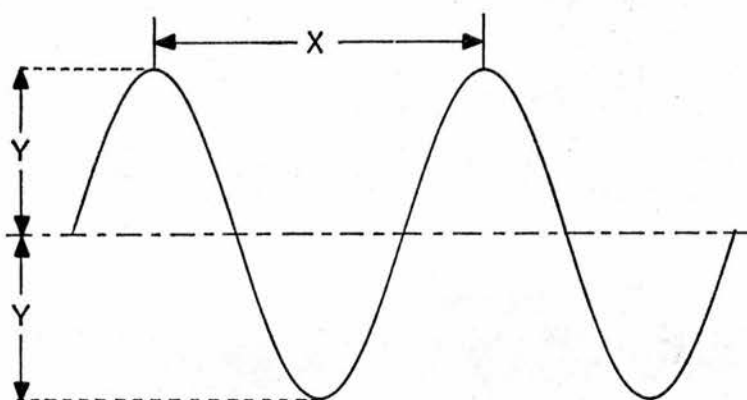
ATTAINMENT TEST II

Take g to be 10 m s^{-2}

Instructions to the candidate:

1. All questions are of the same kind. There is only one answer required to each question and there are no trick questions.
2. Each question consists of alternative answers lettered A, B, C, D or E, and your choice should be indicated in **pencil** by a tick (\checkmark) in the answer sheet provided. **Be very careful to put the tick in the correct square.** If you change your mind, erase the tick completely. Two replies to one question will result in loss of marks for that question.
3. Mathematical tables and other relevant data are provided.
4. All questions should be attempted.
5. Rough working must be done only on the paper provided. Do **not** write on any part of the question paper.
6. Make sure that only **one** of the alternatives is ticked in each case.
7. At the end of the examination, both question paper and answer sheet must be handed in.

1. A wave profile is shown below.



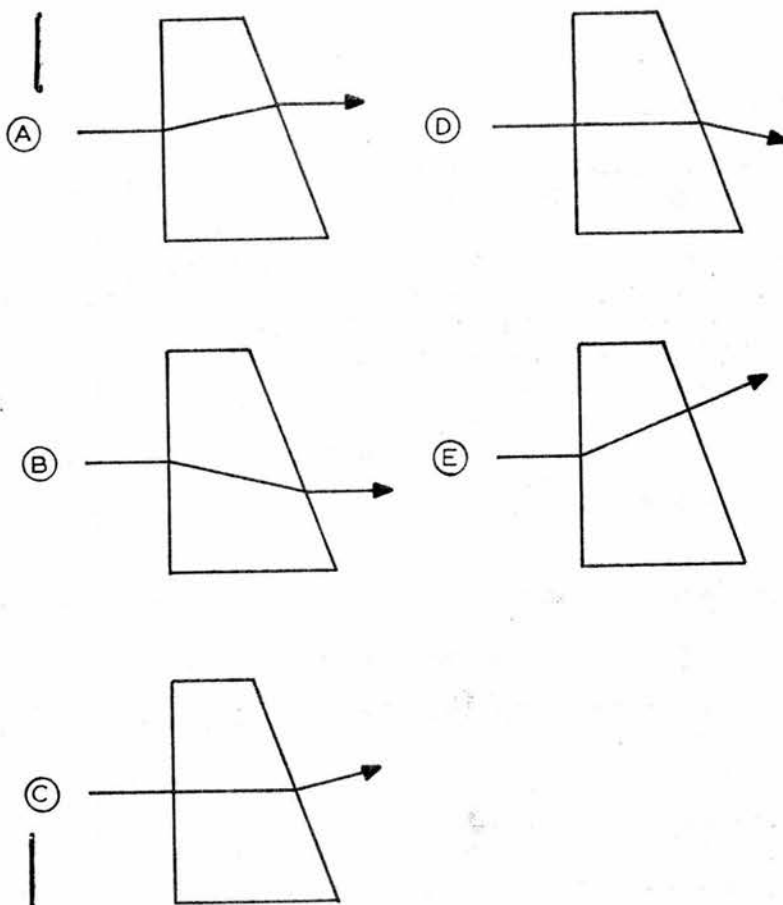
What are X and Y called?

	X	Y
A	frequency	wavelength
B	frequency	amplitude
C	wavelength	amplitude
D	wavelength	frequency
E	amplitude	wavelength

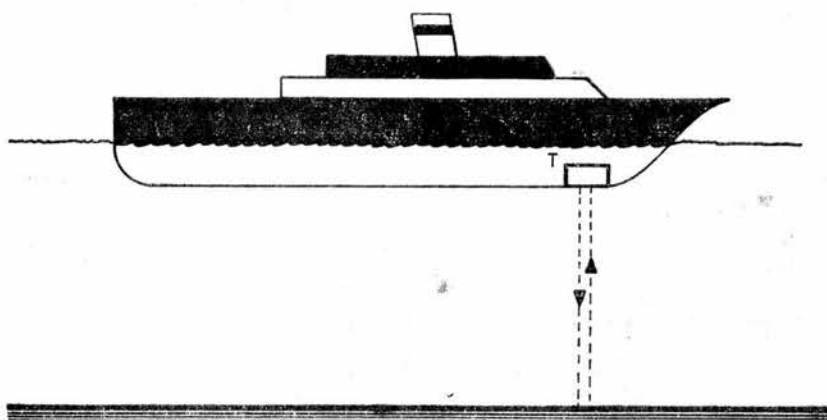
2. What property of a sound wave changes as the sound gets louder?

- A Amplitude.
- B Direction.
- C Frequency.
- D Velocity.
- E Wavelength.

3. A ray of light strikes a glass slab at right angles to the side of the slab. What is the path of the ray through the glass?



4. Sonar can be used to measure the depth of water beneath a ship. A sound pulse sent out by transmitter T is reflected from the sea-bed. The time interval between the pulse leaving and returning to the transmitter is 0.05 s. Sound travels at 1410 m s^{-1} in water.



The depth of water in metres beneath the ship is;

- A 1410×0.05
- B $1410 \times 0.05 \times 2$
- C $\frac{1410 \times 0.05}{2}$
- D $\frac{1410}{0.05}$
- E $\frac{1410}{0.05 \times 2}$

5. A man standing at a distance from the source of an explosion and looking towards it hears the sound of the explosion;
- A always before he sees the flash
 - B at a time either before or after he sees the flash depending on how loud the explosion is
 - C always at the same time as he sees the flash
 - D at a time either before or after the flash depending on how far away the explosion is
 - E always after he sees the flash.

6. Which of these physical quantities is a scalar?

- A Acceleration.
- B Displacement.
- C Kinetic energy.
- D Momentum.
- E Velocity.

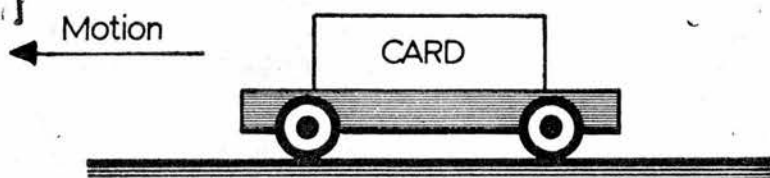
7. A vehicle moves with a uniform acceleration. This means that it has a uniform rate of change of:

- A acceleration
- B velocity
- C position
- D displacement
- E energy.

8. What is the unit of acceleration?

- A kg m s^{-1} .
- B m s^{-1} .
- C m s^{-2} .
- D kg m s^{-2} .
- E N m.

9. An accelerating trolley has a length of card attached.

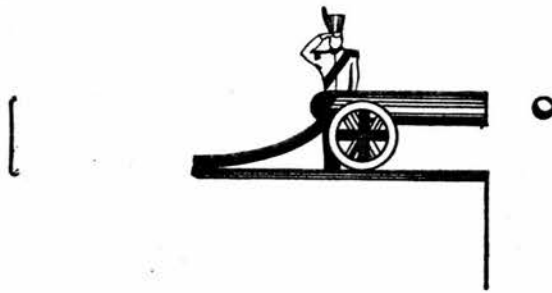


The card moves through a photo-electric timer. The time it takes is recorded on a clock.

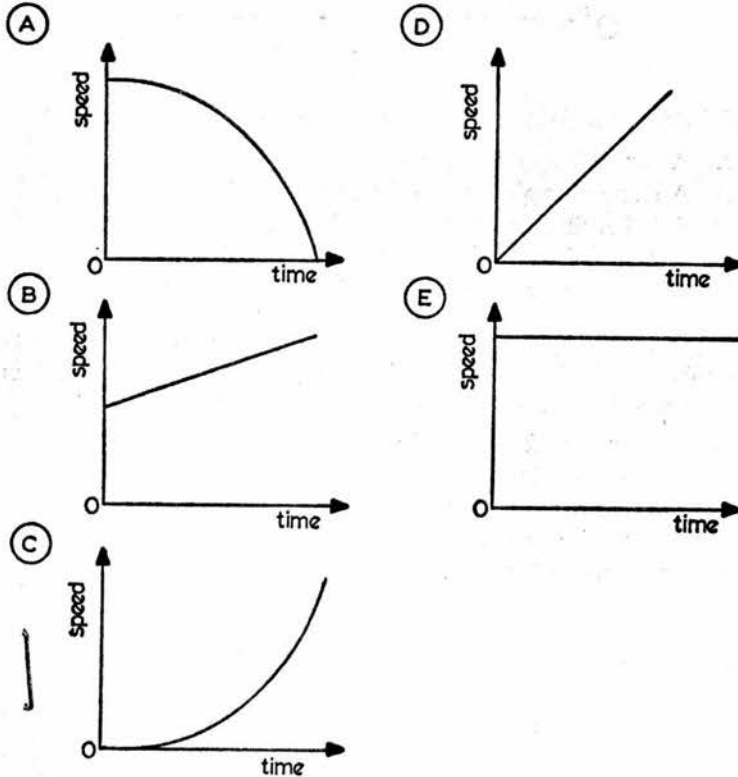
The length of the card is then divided by the time taken. What information does this calculation give about the motion of the trolley during this time?

- A Total displacement.
- B Average displacement.
- C Instantaneous acceleration.
- D Average acceleration.
- E Average velocity.

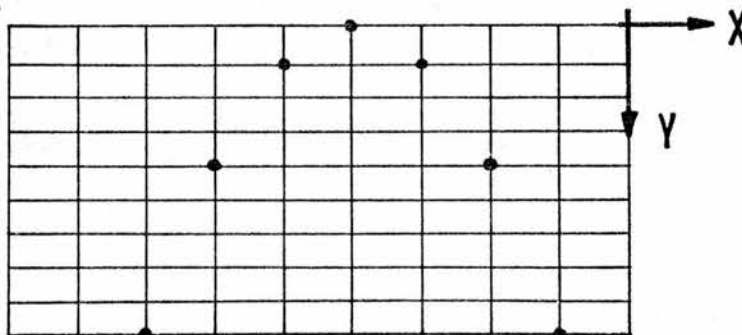
10. A projectile is fired horizontally from the top of a cliff.



What does a graph of the horizontal velocity of the projectile look like from the moment it leaves the launcher until it hits the water?



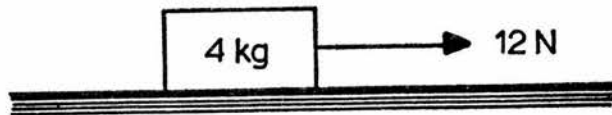
11. Here is a stroboscopic photograph of a moving body showing its instantaneous position at equal time intervals.



The body is moving under the influence of;

- A two forces; one in direction x , one in direction y
 B a force in direction x only
 C a force in direction y only
 D a force in a direction which changes continuously
 E no force.

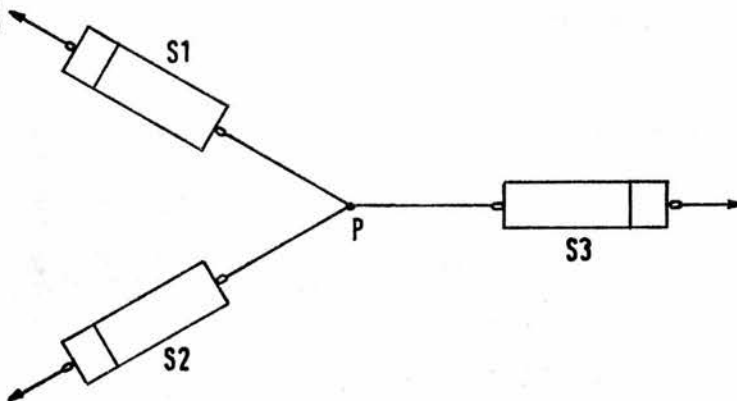
12. A block of mass 4 kg pulled along a horizontal surface by a 12 N force accelerates at a rate of 2 m s^{-2} .



The frictional force opposing motion is:

- A 4 N
B 20 N
C 32 N
D 40 N
E 46 N.

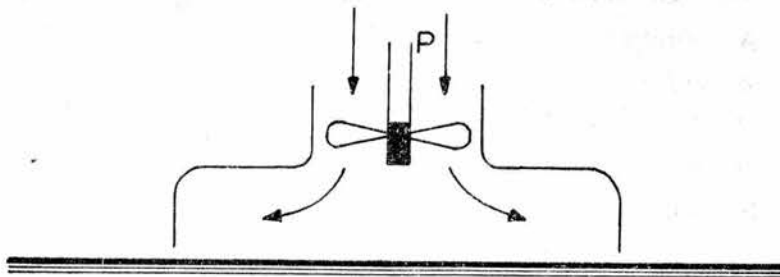
13. The diagram shows three strings tied at point P which is at rest and attached to three spring balances S_1 , S_2 and S_3 .



Which set of spring balance readings is possible?

	spring balance S_1 (newtons)	spring balance S_2 (newtons)	spring balance S_3 (newtons)
A	1	1	2
B	1	1	3
C	2	2	5
D	2	2	3
E	3	3	7

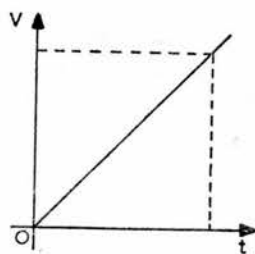
14. The outline of a Hovercraft is shown below. It is kept hovering above the ground by air which is blown downwards by propeller P. The mass of the Hovercraft is $2 \times 10^3 \text{ kg}$.



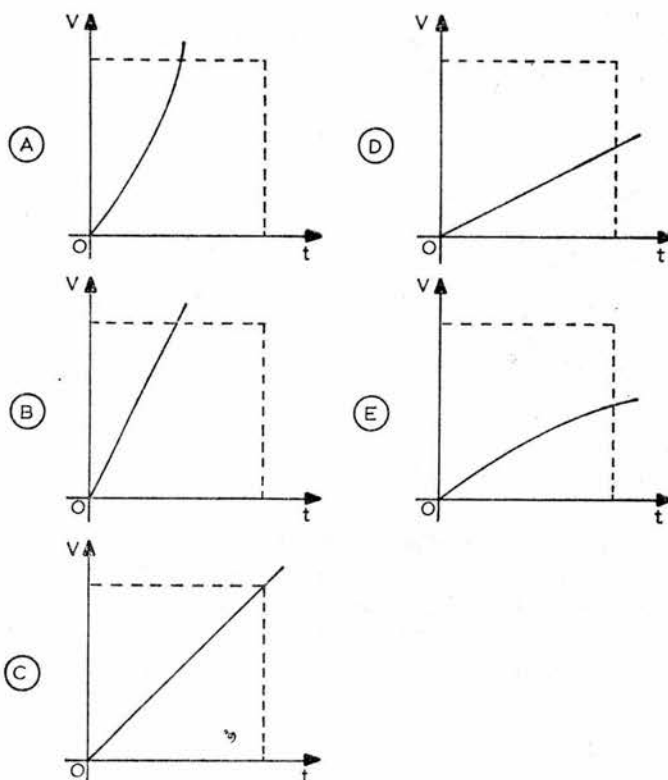
What upward force in newtons is exerted to keep the Hovercraft hovering?

- A Zero.
B 10.
C 2×10^2 .
D 2×10^3 .
E 2×10^4 .

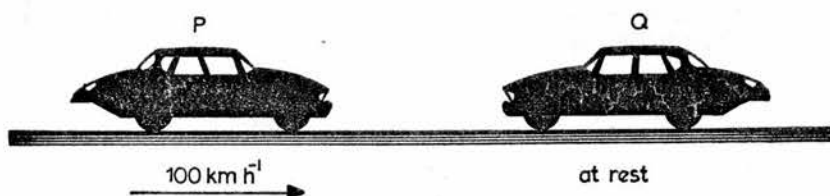
15. Part of the speed-time graph of a freely falling body of mass m is shown.



What is the corresponding speed-time graph of a freely falling body of mass $2m$?



16. A car P moving with speed 100 km h^{-1} collides head-on with an identical stationary car Q. The two vehicles lock together and continue moving in the original direction of P.

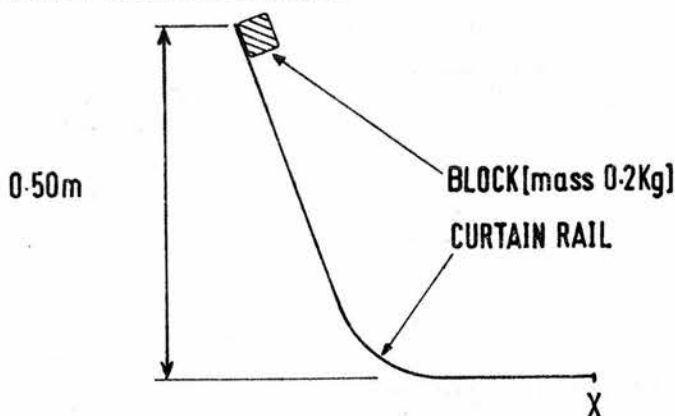


What is the speed of the wreckage?

- A zero
B 50 km h^{-1}
C 100 km h^{-1}
D 150 km h^{-1}
E 200 km h^{-1} .
17. An object of mass 5 kg is dropped from rest at a height of 4 m . It rebounds to a height of 3 m . What is the kinetic energy of the object just after rebound?

- A 15 J .
B 20 J .
C 50 J .
D 150 J .
E 200 J .

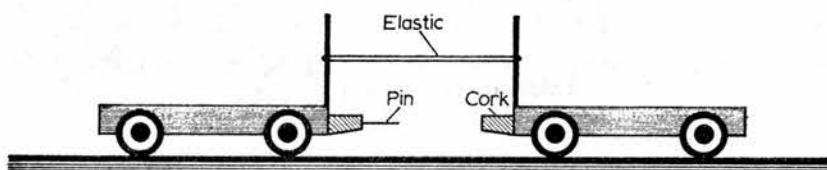
18. A block of mass 0.20 kg slides from rest down a curtain rail shaped as shown. Friction is negligible.



When it leaves the curtain rail at X the block has kinetic energy of;

- A 0.10 J
- B 0.40 J
- C 1.0 J
- D 2.5 J
- E 4.0 J

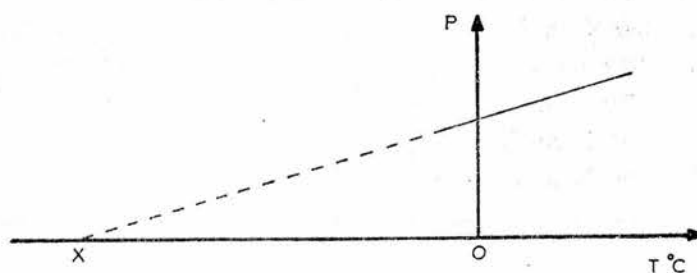
19. The system below consists of two identical trolleys connected by a stretched elastic band. The trolleys are held a few centimetres apart on a horizontal table and then released.



During the time the trolleys are moving towards one another which physical quantity is the same for both?

- A Average momentum.
- B Average velocity.
- C Average acceleration.
- D Average kinetic energy.
- E Average displacement.

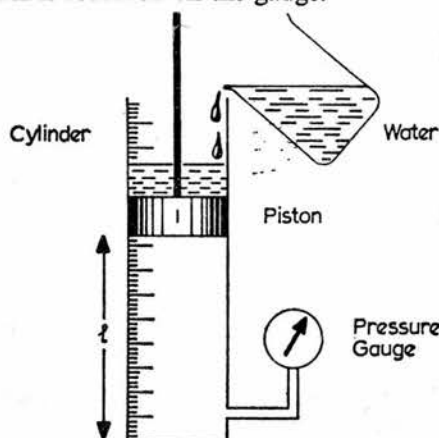
20. The graph shown is obtained in an experiment to find the relation between the pressure P and the temperature T of a given mass of gas at a fixed volume.



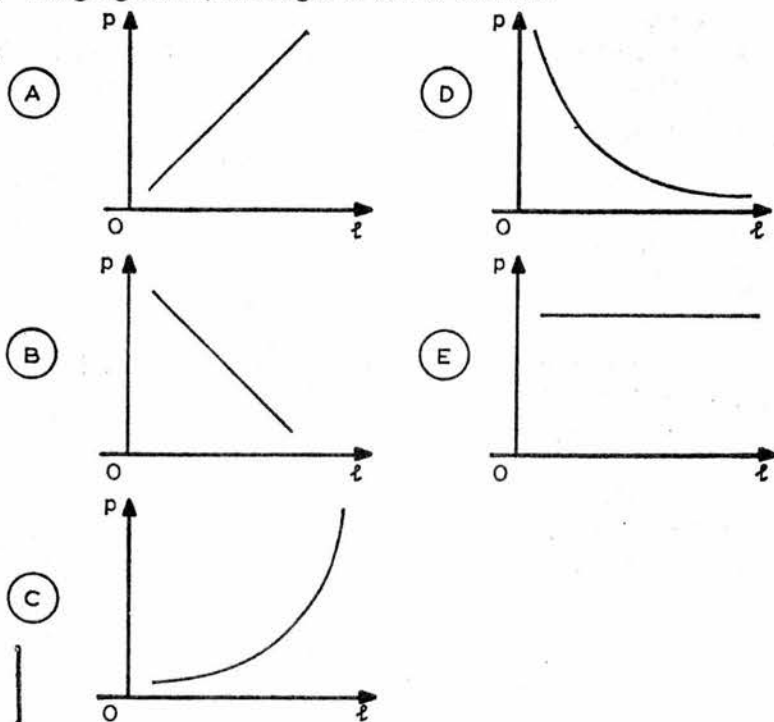
The pressure at point X on the graph is zero. What is the temperature at X?

- A 273°C .
- B 100°C .
- C 0°C .
- D -100°C .
- E -273°C .

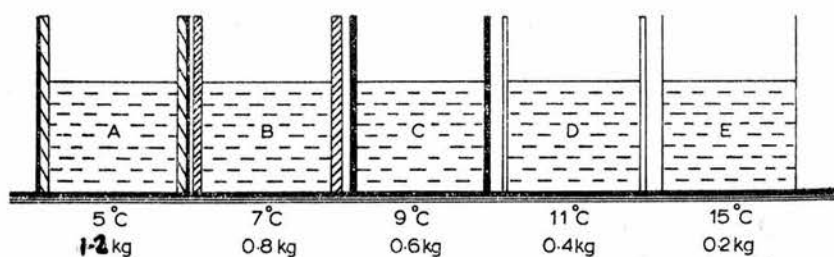
21. The specific latent heat of fusion of a substance is 4000 J kg^{-1} . This means that it takes;
- A 4000 joules to raise the temperature of 1 kg of the substance by 1 K
 - B 4000 joules to raise the temperature of 1 kg of the substance from the melting point to the boiling point of the substance
 - C 4000 joules to raise the temperature of 1 kg of the substance by 273 K
 - D 4000 joules to change 1 kg of the substance from solid to liquid at the melting point of the substance
 - E 4000 joules to change 1 kg of the substance from liquid to gas at the boiling point of the substance.
22. The diagram shows an air-tight piston being forced down a graduated cylinder by the weight of the water above it. The pressure of the air in the cylinder is recorded on the gauge.



What relation would you expect between the pressure p as read on the gauge and l , the length of the air column?



23. Equal masses of hot water at the same temperature are poured into containers made of different materials. The mass of each container and its final rise in temperature due to the hot water is indicated.



Which container material has the lowest specific heat capacity?

To which container is the temperature drop of the water greatest?

24. Study the following heat data.

<i>Metal</i>	<i>Specific heat capacity J kg⁻¹ °C⁻¹</i>
iron	500
zinc	400
tin	250

Two metal blocks *X* and *Y* each of mass 1 kg have identical electric immersion heaters inserted in them. Both heaters are switched on for two minutes. As a result the temperature of *X* rises by 48°C and that of *Y* by 24°C.

It can be deduced that;

- A *X* is tin, *Y* is zinc
- B *X* is zinc, *Y* is tin
- C *X* is zinc, *Y* is iron
- D *X* is iron, *Y* is tin
- E *X* is tin, *Y* is iron.

25. Here are some data:

specific heat capacity of iron = 500 J kg⁻¹ °C⁻¹

specific heat capacity of copper = 420 J kg⁻¹ °C⁻¹.

From these data it can be concluded that, for equal masses of iron and copper:

- A iron needs more energy than copper to melt it at its melting point
- B iron needs less energy than copper to melt it at its melting point
- C equal quantities of energy will produce a greater temperature rise in the iron than in the copper
- D equal quantities of energy will produce a greater temperature rise in the copper than in the iron
- E supplying more energy to the copper than to the iron produces the same rise of temperature in both.

26. An immersion heater is used to heat a mass of liquid for an unspecified time. To calculate the maximum possible rise in temperature of the liquid what information is required?

	<i>Specific heat capacity of liquid</i>	<i>Power rating of heater</i>	<i>Mass of liquid</i>	<i>Time of heating liquid</i>
A	Yes	No	Yes	No
B	Yes	Yes	No	Yes
C	Yes	Yes	Yes	Yes
D	No	Yes	No	Yes
E	No	No	Yes	Yes

27. What is the unit of potential difference?

- A Ampere.
- B Joule.
- C Ohm.
- D Volt.
- E Watt.

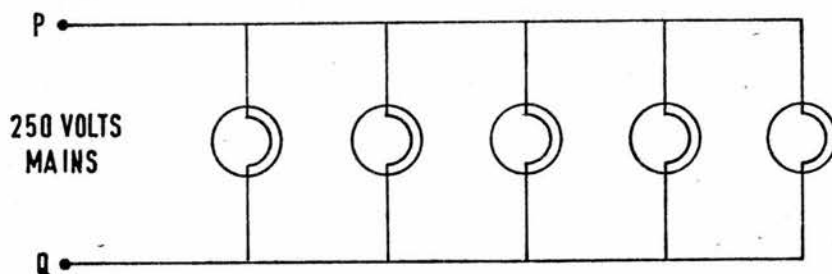
28. A current of '7 microamperes' is equivalent to a current of:

- A 7×10^{-9} A
- B 7×10^{-6} A
- C 7×10^{-3} A
- D 7×10^3 A
- E 7×10^6 A.

29. What is the name of the semi-conductor device used in electric circuits to amplify small electric currents?

- A Diode valve.
- B Solid state diode.
- C Thermistor.
- D Transformer.
- E Transistor.

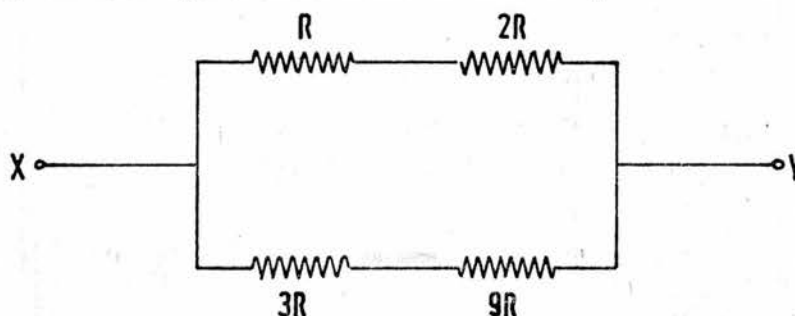
30. In this circuit each light has a filament resistance of $250\ \Omega$.



What is the resistance across PQ?

- A $\frac{1}{250}\ \Omega$.
- B $\frac{1}{50}\ \Omega$.
- C $50\ \Omega$.
- D $250\ \Omega$.
- E $1250\ \Omega$.

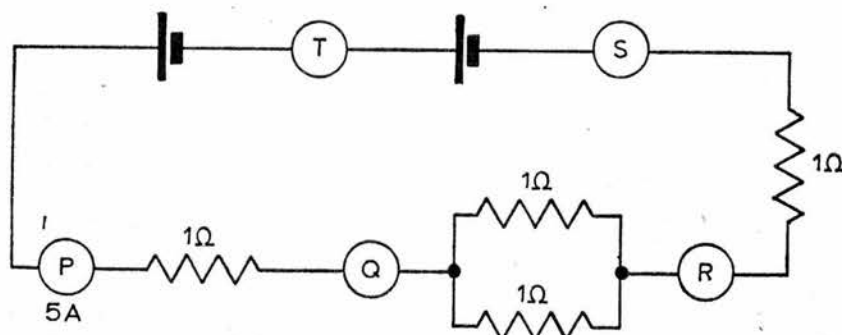
31. In the arrangement of resistors shown the voltage across XY is 6 V



What is the potential difference across the $2R$ resistor?

- A 1.5 V .
- B 2.0 V .
- C 4.0 V .
- D 4.5 V .
- E 6.0 V .

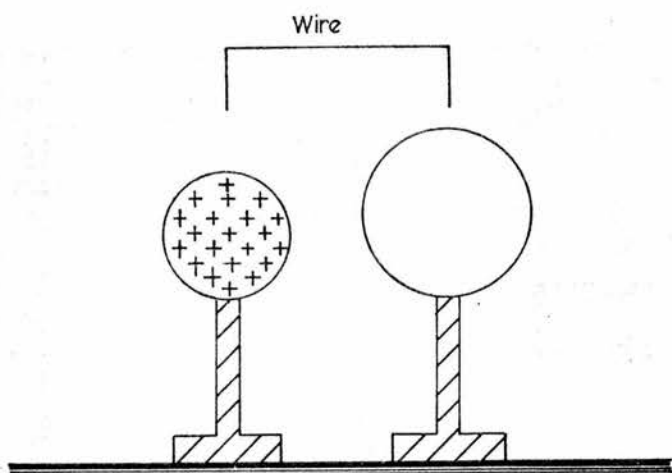
32. In the circuit shown below each of the resistors has value $1\ \Omega$. Ammeter P reads 5 amperes .



What are the readings on the other ammeters Q , R , S and T ?

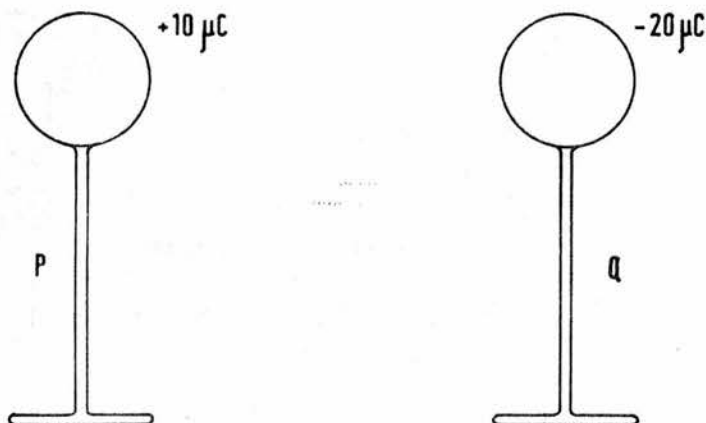
	Q	R	S	T
A	4 A	2 A	1 A	zero
B	4 A	2 A	1 A	1 A
C	4 A	3 A	2 A	1 A
D	5 A	5 A	5 A	zero
E	5 A	5 A	5 A	5 A

33. Two metal spheres are mounted on insulating stands. The larger one is uncharged and the smaller one is positively charged.



When the two spheres are joined by a wire;

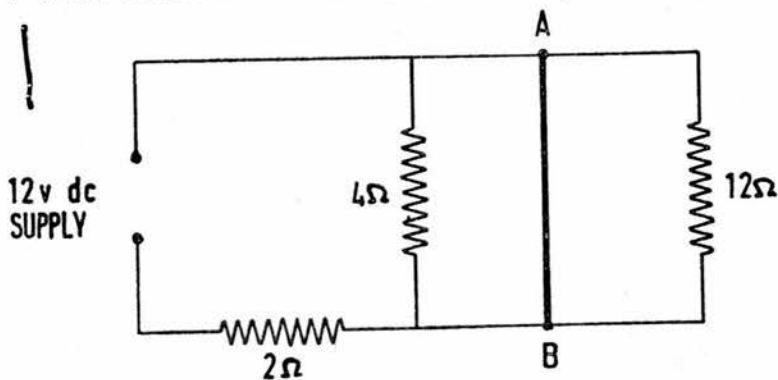
- A positive charges on the smaller all flow to the larger leaving the smaller sphere uncharged
 - B positive charges flow from the smaller to the larger until the charge on both spheres is the same
 - C positive charges flow from the smaller to the larger until the potential of both spheres is the same
 - D electrons flow from the larger to the smaller until the charge on both spheres is the same
 - E electrons flow from the larger to the smaller until the potential of both spheres is the same.
34. P and Q are identical metal spheres on insulated stands. The charge on P is $+10$ microcoulombs and the charge on Q is -20 microcoulombs. The following four separate actions are carried out momentarily in the sequence shown;
 P is earthed; then touched to Q ;
 Q is earthed; then touched to P .



After these actions the charges on P and Q , in microcoulombs are;

	P	Q
A	0	0
B	+5	-5
C	-10	-10
D	-5	-5
E	-5	0

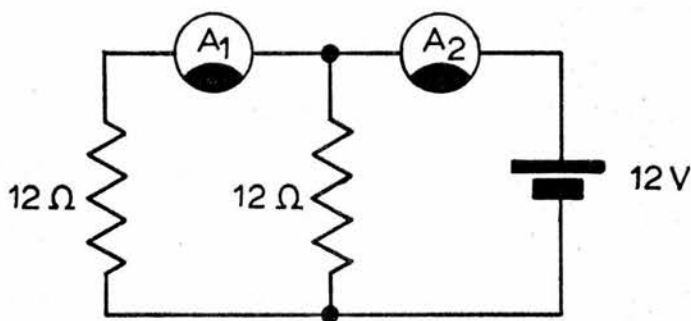
- 35 . In the circuit shown A and B are connected by a thick copper wire.



What current is taken from the supply?

- A. Zero.
- B. 0.5 A.
- C. 2.0 A.
- D. 6.0 A.
- E. A very large current which it is not possible to calculate.

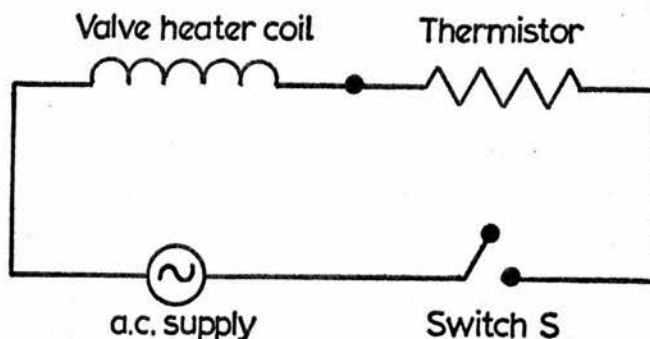
- 36 . In the circuit below A_1 and A_2 are identical ammeters of negligible resistance.



What are the readings on A_1 and A_2 ?

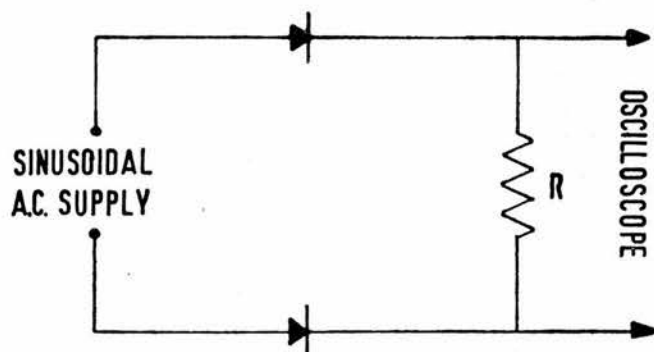
	Reading on A_1	Reading on A_2
A	0.5 A	0.25 A
B	0.5 A	0.5 A
C	1 A	1 A
D	1 A	2 A
E	2 A	2 A

- 37 . In the circuit below a valve heater coil is connected in series with a thermistor. It is known that as they heat up the resistance of the coil increases at the same rate as the resistance of the thermistor decreases.

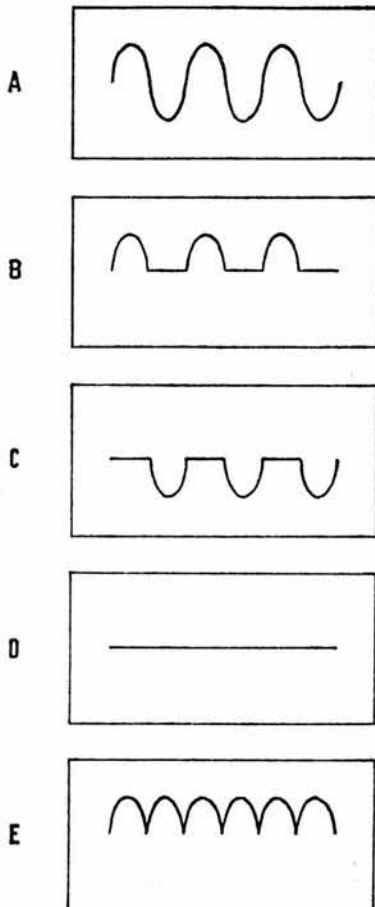


When switch S is closed how do the currents in the heater coil and in the thermistor change as the components heat up?

- A. Current in both components remains constant.
- B. Current in both components increases.
- C. Current in both components decreases.
- D. Current increases in the heater coil and decreases in the thermistor.
- E. Current decreases in the heater coil and increases in the thermistor.



What trace appears on the screen?



39. A radioactive source is kept in a school laboratory and used from time to time to demonstrate the properties of alpha, beta and gamma emission.

What is a suitable half-life of such a source?

- A 5 seconds.
 B 1 minute.
 C 3 days.
 D 1 month.
 E 1600 years.

40. The nuclide $^{228}_{89}\text{Ac}$ is formed from a naturally occurring nuclide X by alpha emission followed by beta emission.

Nuclide X is;

- A $^{238}_{92}\text{U}$
 B $^{232}_{90}\text{Th}$
 C $^{233}_{91}\text{Pa}$
 D $^{234}_{92}\text{U}$
 E $^{230}_{90}\text{Th}$.

APPENDIX VI

SCE II: QUESTION PAPER FOR THE SCOTTISH
CERTIFICATE OF EDUCATION IN PHYSICS AT
THE ORDINARY GRADE.

1973 PAPER II.

SCOTTISH CERTIFICATE OF EDUCATION

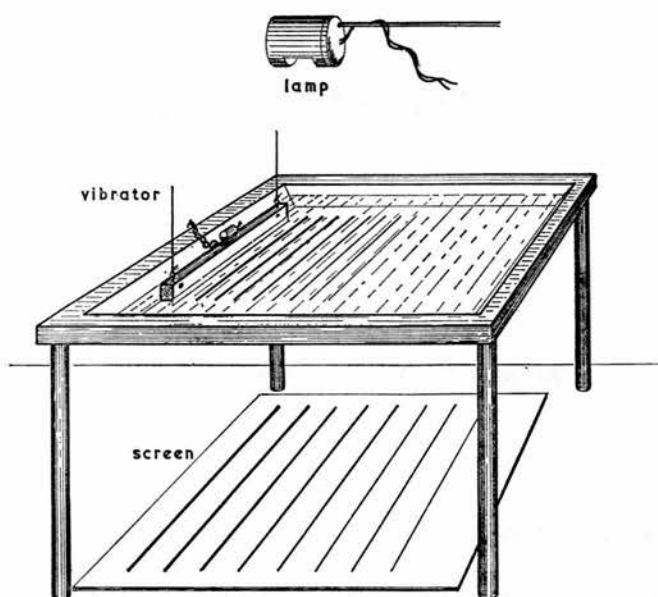
PHYSICS

Ordinary Grade—Paper II

Monday, 7th May—11.00 a.m. to 12.30 p.m.

Answer any FIVE questions.**You may use the approximation $g = 10 \text{ m s}^{-2}$ or $g = 10 \text{ N kg}^{-1}$.****Any other data required will be found in the book of Mathematical Tables and Science Data provided.****You should note that in this paper the negative index has been used in unit symbol abbreviations such as m s^{-2} . This has the same meaning as the alternative form m/s^2 .****Marks may be deducted for bad spelling and bad punctuation, and for writing that is difficult to read.****[167]**

1. (a) The pattern of water waves produced by a vibrator in a ripple tank is viewed on a screen by illuminating the tank using a lamp as shown.



Describe how you would measure

- (i) the frequency,
- (ii) the wavelength of the waves.

If you knew the value of the velocity of the waves, how could you use it to check the results of your measurements in (i) and (ii)?

(5)

- (b) How would you demonstrate the refraction of water waves in the ripple tank? Indicate any additional apparatus you require.

Describe what would be observed.

(3)

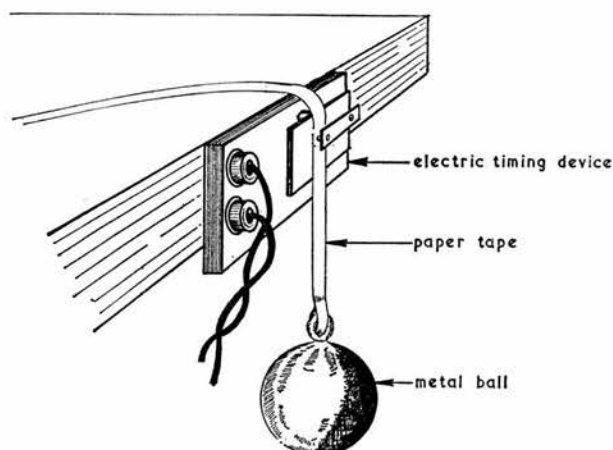
- (c) Name any instrument which depends on refraction and explain very briefly how the operation of the instrument depends on refraction.

(2)

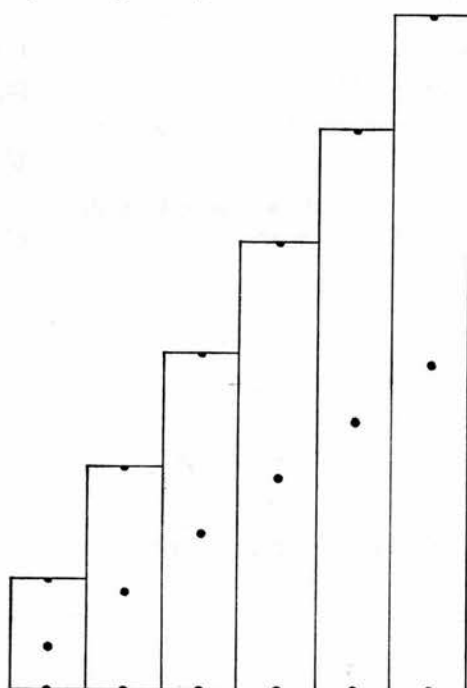
2. A large packing case of mass 500 kg rests on the ground. A fork-lift truck raises it 1.5 m, transports it at a steady speed of 2.0 m s^{-1} and deposits it on the loading platform of a lorry.

- (a) (i) What is the minimum upward force exerted by the fork-lift? (1)
- (ii) How much potential energy is gained by the packing case? (2)
- (b) (i) Calculate the kinetic energy of the packing case while it is being transported at the steady speed. (2)
- (ii) What happens to this kinetic energy when the fork-lift truck stops? (2)
- (c) If the fork-lift uses energy at the rate of 25 kW and the lifting operation takes 3.0 seconds, calculate the apparent efficiency of this operation. (3)

3. In the apparatus shown in the diagram, the electric timing device prints 50 dots every second on the tape. When the ball is allowed to fall, a record of its motion is produced on the tape.

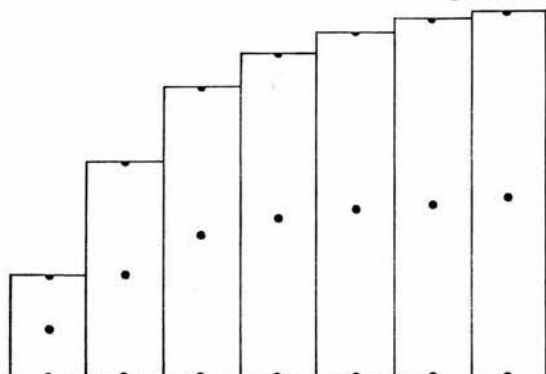


By cutting the tape at each alternate dot, the following tape-chart (actual size) is obtained.



- (a) Calculate the average acceleration. (3)
- (b) Compare your answer with the accepted value for the acceleration due to gravity and suggest an explanation for the difference. (2)

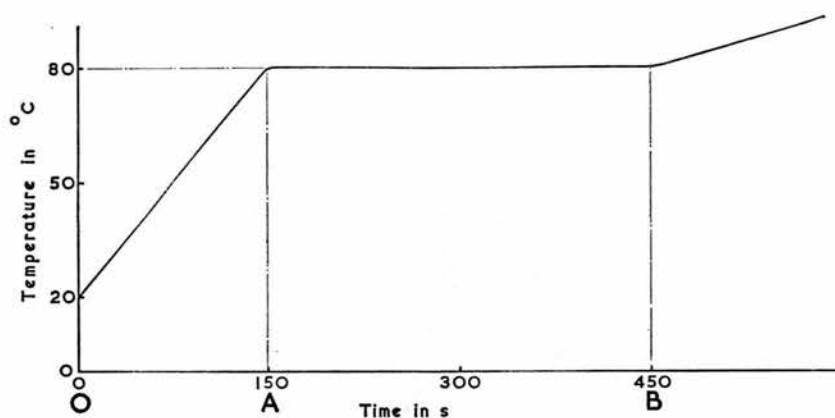
The experiment is repeated using a light polystyrene ball instead of the metal one and this second tape-chart shows the result of the modified experiment.



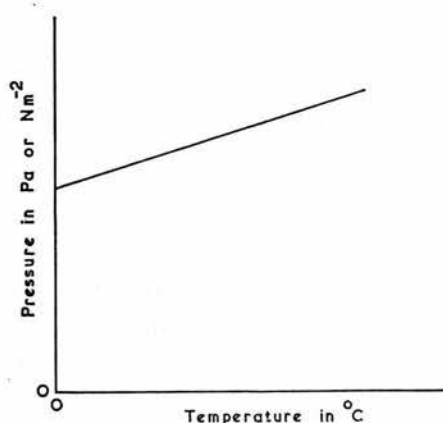
- (c) Describe what this indicates about
- the speed,
 - the acceleration,
 - the unbalanced force acting on the polystyrene ball.
- (5)

[Turn over

4. (a) A test tube containing 0.10 kg of a powder is heated for several minutes by a bunsen burner which is supplying heat at a constant rate of 50 joules per second. The temperature of the contents is noted at equal time intervals and a graph of temperature against time drawn.



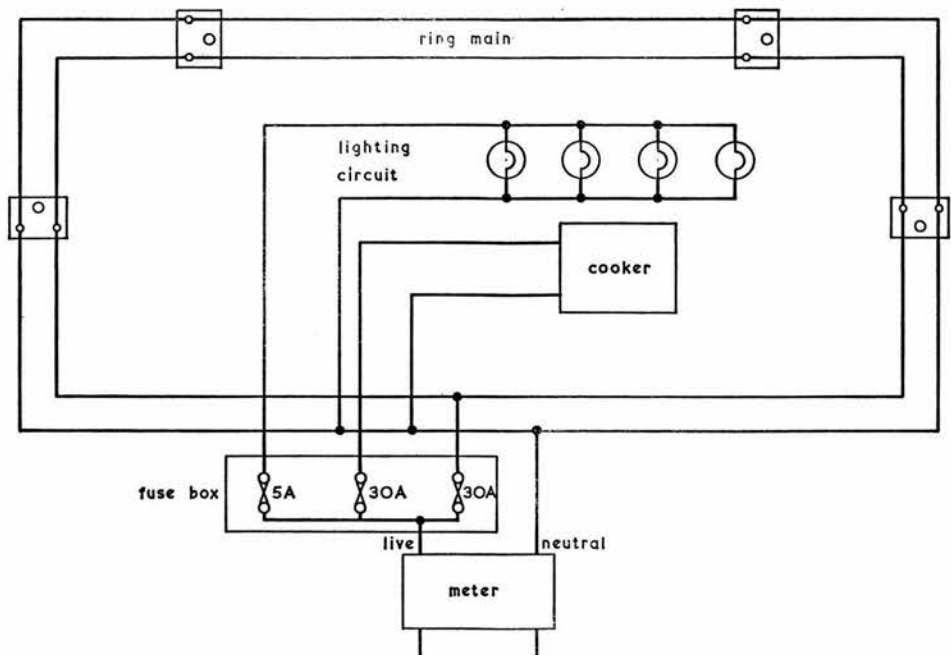
- (i) Express the power output of the bunsen burner in watts. (1)
 - (ii) What is happening to the substance during the interval OA? (1)
 - (iii) What is happening to the substance during the interval AB? (1)
 - (iv) What is the significance of the time AB being greater than the time OA? (2)
 - (v) Calculate the specific heat capacity of the powder, assuming that all the heat supplied by the bunsen is transferred to the powder. (3)
- (b) A characteristic of certain cooking pots is that when they are removed from the source of heat, the contents may continue to boil for a short time. Suggest an explanation for this effect. (2)
5. (a) In an explanation of Brownian motion the expression "random motion" is often used.
- (i) What is meant by "random motion"? (1)
 - (ii) Explain the change which would occur if the temperature of the contents of the vessel in which the Brownian motion was being observed were raised. (2)
- (b) The graph shows the results of an examination of the pressure of a given mass of gas, kept at constant volume, as its temperature is varied.



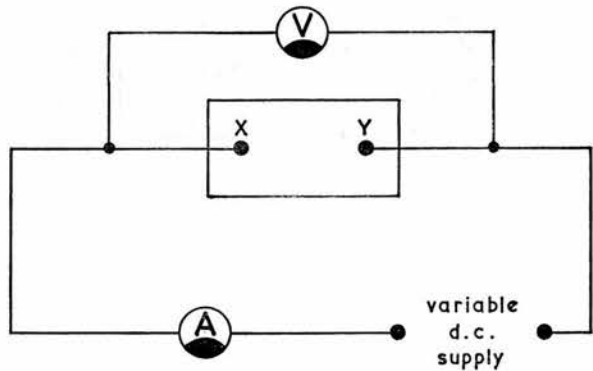
- (i) Explain how the graph can be used to establish a mathematical relationship between pressure and temperature. (4)
- (ii) Explain this relationship in terms of the motion of the particles of the gas. (3)

6. The diagram shows part of a house-wiring system.

Marks



- (a) There are usually about ten 13 A points in the ring main. Why is a 30 A fuse considered suitable for this circuit? (1)
- (b) If the 30 A cooker fuse “blew”, what would happen to the components in the other circuits, e.g. lighting, ring main? (2)
- (c) No earth connections are shown in the diagram. Why are such connections required? (2)
- (d) What physical quantity does the meter measure? (1)
- (e) If a heater rated at 240 V, 2 kW were to be connected in the ring main, what value of fuse (2 A, 5 A, 10 A, or 13 A) would it be advisable to fit in the plug? (2)
- (f) What difference would you expect to find between the wire used in the lighting and the ring main circuits? Explain your answer. (2)
7. An electrical component is contained in a closed box. Two terminals from the component are connected in the circuit at X and Y as shown.



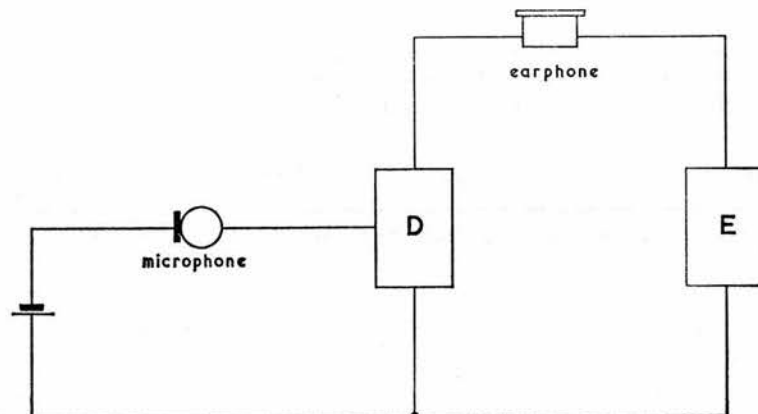
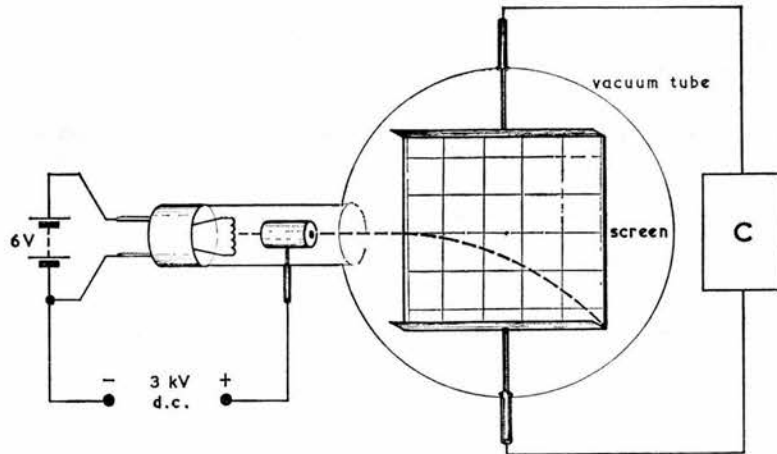
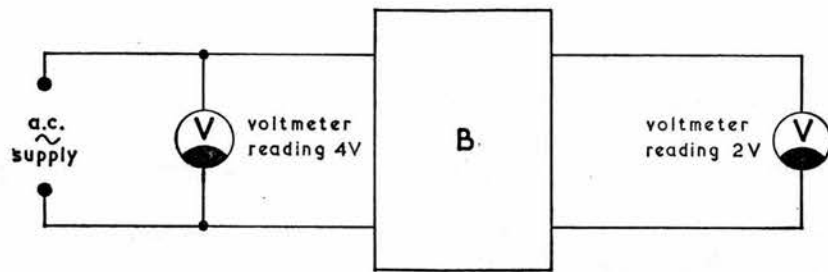
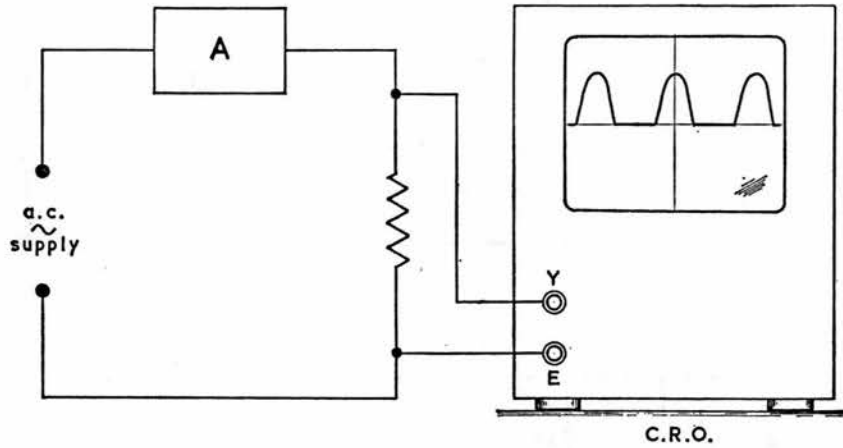
A pupil is asked to examine the relationship between the voltage across XY and the current in the circuit. He gradually increases the voltage and obtains the following results:

V volts	1.0	2.0	3.0	4.0	5.0
I amperes	0.20	0.27	0.34	0.36	0.37

- (a) Calculate the value of the resistance of the box from the fourth set of results, namely $V = 4.0$ V, $I = 0.36$ A. (2)
- (b) Draw a graph of I against V . (2)
- (c) What conclusion regarding the resistance of the contents can be drawn from the graph? (2)
- (d) In what way does the shape of the graph differ from what you might have been led to expect from the law connecting current and voltage? (2)
- (e) On looking inside the box, the pupil discovers it contains a torch bulb. Use your knowledge of a bulb to explain the conclusion in part (c). (2)

8. The diagrams show experiments in which important components have been omitted, and are indicated by capital letters.

State what each of the items A, B, C, D and E is, and **briefly** describe its purpose in its circuit.



[END OF QUESTION PAPER]

APPENDIX VII

**Analysis of Covariance of Dependent Variables
Using Best 'Weighted' Composite of Covariates**

- Statistical Procedure -

APPENDIX VII

Analysis of Covariance of Dependent Variables Using Best 'Weighted' Composite of Independent Variables as Covariates.

Statistical Procedure

This appendix indicates how analysis of covariance is used to adjust the student's scores z_1 , z_2 and z_3 in the tests of cognitive attainment to take account of inter-style differences in student variables x and y representing IQ and social status respectively.

Procedure

1. For each test intercorrelations between the independent variables x and y with the appropriate dependent variables z_1 , z_2 and z_3 are calculated.

The general form of these is:-

$$r_{xy}(\text{within}) = \frac{\sum_j \left[\sum_i x_{ij} y_{ij} - \left(\sum_i x_{ij} \right) \left(\sum_i y_{ij} \right) / n_j \right]}{\sqrt{\left[\sum_j \left\{ \sum_i x_{ij}^2 - \left(\sum_i x_{ij} \right)^2 / n_j \right\} \right] \left[\sum_j \left\{ \sum_i y_{ij}^2 - \left(\sum_i y_{ij} \right)^2 / n_j \right\} \right]}} \quad (1)$$

where $i = 1, 2, \dots, n_j$, the number of observations in group j ,
and $j = 1, 2, 3$.

and

$$r_{xy}^1(\text{total}) = \frac{\sum_j \sum_i x_{ij} y_{ij} - \left(\sum_j \sum_i x_{ij} \right) \left(\sum_j \sum_i y_{ij} \right) / \sum_j n_j}{\sqrt{\left\{ \sum_j \sum_i x_{ij}^2 - \left(\sum_j \sum_i x_{ij} \right)^2 / \sum_j n_j \right\} \left\{ \sum_j \sum_i y_{ij}^2 - \left(\sum_j \sum_i y_{ij} \right)^2 / \sum_j n_j \right\}}} \quad (2)$$

These are respectively the 'Within' and 'Total' correlations between the independent variables x and y. 'Within' and 'Total' correlations between each of these independent variables and each of the dependent variables z_1 , z_2 and z_3 are obtained similarly, giving:

r_{xy} , r_{xz_1} , r_{xz_2} , r_{xz_3} , r_{yz_1} , r_{yz_2} , r_{yz_3} and the corresponding 'Total' correlation coefficients r_{xy}^1 , $r_{xz_1}^1$, ... $r_{yz_3}^1$.

2. Partial regression coefficients in standard form are derived from these intercorrelations as follows:-

$$\beta_{z_1x y} = \frac{r_{z_1x} - r_{z_1y}r_{xy}}{1 - r_{xy}^2} \quad (3) \quad \beta_{z_1y x} = \frac{r_{z_1y} - r_{z_1x}r_{xy}}{1 - r_{xy}^2} \quad (4)$$

$$\beta'_{z_1x y} = \frac{r_{z_1x}^1 - r_{z_1y}^1 r_{xy}^1}{1 - r_{xy}^{12}} \quad (5) \quad \beta'_{z_1y x} = \frac{r_{z_1y}^1 - r_{z_1x}^1 r_{xy}^1}{1 - r_{xy}^{12}} \quad (6)$$

where β and β' denote the 'Within' and 'Total' beta 'weights' respectively; giving the 'Within' regression coefficients;

$\beta_{z_1x y}$; $\beta_{z_1y x}$; $\beta_{z_2x y}$; $\beta_{z_2y x}$; $\beta_{z_3x y}$; $\beta_{z_3y x}$; and the corresponding 'Total' regression coefficients;

$\beta'_{z_1x y}$... $\beta'_{z_3y x}$.

3. The 'Within' and 'Total' standard deviations s and s' respectively are calculated as shown in equations (7) and (8):

$$S_{x(\text{Within})} = \sqrt{\frac{X_W}{\sum n - g}} \quad (7) \quad \text{and}$$

$$S_{x(\text{Total})}^1 = \sqrt{\frac{X_T}{\sum n - 1}} \quad (8)$$

where X_W and X_T are the 'Within' and 'Total' sums of squares for x . $\sum n$ is the total number of observations of x over all groups and g is the number of treatment groups. The 'Within' standard deviations $s_x, s_y, s_{z_1}, s_{z_2}, s_{z_3}$ and the corresponding 'Total' standard deviations $s_x^1 \dots s_{z_3}^1$ are computed.

4. The standardised partial regression coefficients calculated in paragraph 2 above are now converted to 'working weights', denoted by W . Each 'beta weight' is converted to its 'working weight' as shown in equations (9) and (10) below.

$$W_{z_1 x y} = \beta_{z_1 x y} \frac{s_{z_1}}{s_x} \quad (9) \quad \text{and}$$

$$W_{z_1 x y}^1 = \beta_{z_1 x y}^1 \frac{s_{z_1}^1}{s_x^1} \quad (10) \quad \text{where } W \text{ and } W^1$$

are the 'Within' and 'Total' 'working weights' respectively; β and β^1 the corresponding 'beta weights' and s and s^1 the 'Within' and 'Total' standard deviations calculated in (3) above. In this way the 'working weights': $W_{z_1 x y}, W_{z_1 y x}, W_{z_2 x y}, W_{z_2 y x},$

$W_{z_3x} y$, $W_{z_3y} x$, and $W_{z_1x}^1 y \dots W_{z_3y}^1 x$ are obtained. It is these 'working weights' which are used in the final adjusted covariance analysis of each of the dependent variables z_1 , z_2 and z_3 . This analysis is shown in paragraph 5 for the case of z_1 .

5. The analysis of covariance of the dependent variable z_1 with the independent variables x and y as covariates is indicated in Table I below.

TABLE I

Analysis of covariance of dependent variable z_1 with the independent variables x and y as covariates.

Source	d.f.	Sums of Squares	Mean Squares
Styles	$g-1$	$\beta - \alpha$	$\beta - \alpha / g-1$
Students	$\sum n - g - 2$	$Z_{1(W)} - (W_{z_1x} y)(XZ_{1(W)}) - (W_{z_1y} x)(YZ_{1(W)}) = \alpha$	$\frac{\alpha}{\sum n - g - 2}$
Total	$\sum n - 3$	$Z_{1(T)} - (W'_{z_1x} y)(XZ_{1(T)}) - (W'_{z_1y} x)(YZ_{1(T)}) = \beta$	-

$Z_{1(W)}$ denotes the 'Within' sum of squares for z_1 , $XZ_{1(W)}$ the 'Within' sum of products for x and z_1 and so on. In computing the sums of squares and sums of products the procedure described by Lindquist (1956, p.57 & 319) may be used.

F is calculated from the ratio of mean squares

$F = \frac{\text{M.S. styles}}{\text{M.S. students}}$ for the appropriate degrees of freedom

$(g-1; \sum n - g - 2)$.

6. To allow the style means of each of the dependent variables to be adjusted to take account of inter-style differences in the independent variables, the regression coefficients b_x and b_y are calculated for each of the dependent variables. Equations (11) and (12) show the regression coefficients for z_1 .

$$b_x = \frac{XZ_1(W)}{X(W)} \text{--- (11) and } b_y = \frac{YZ_1(W)}{Y(W)} \text{--- (12) where } XZ_1(W)$$

represents the 'within' sum of products of x and z_1 ; $X(W)$ the 'within' sum of squares of x and so on. The experimental means $\bar{x} = \frac{\sum x}{\sum n}$ and $\bar{y} = \frac{\sum y}{\sum n}$ over all styles are calculated and used to compute the adjusted style means shown in Table II.

TABLE II
Table of adjusted means of z_1

Style	n	\bar{X} ($\bar{X}-\bar{x}$)	$b_x(\bar{X}-\bar{x})$	\bar{Y}	$(\bar{Y}-\bar{y})$
(1) Open-ended	n_1	\bar{X}_1 $\bar{X}_1-\bar{x}$	$b_x(\bar{X}_1-\bar{x})$	\bar{Y}_1	$(\bar{Y}_1-\bar{y})$
(2) Intermediate	n_2	\bar{X}_2 $\bar{X}_2-\bar{x}$	$b_x(\bar{X}_2-\bar{x})$	\bar{Y}_2	$(\bar{Y}_2-\bar{y})$
(3) Expository	n_3	\bar{X}_3 $\bar{X}_3-\bar{x}$	$b_x(\bar{X}_3-\bar{x})$	\bar{Y}_3	$(\bar{Y}_3-\bar{y})$
$b_y (\bar{Y}-\bar{y})$	\bar{Z}_1	$\bar{Z}_1(Adj) = \bar{Z}_1 - b_x(\bar{X}-\bar{x}) - b_y (\bar{Y}-\bar{y})$			
(1) $b_y (\bar{Y}_1-\bar{y})$	\bar{Z}_{11}	$\bar{Z}_{11}(Adj) = \bar{Z}_{11} - b_x(\bar{X}_1-\bar{x}) - b_y (\bar{Y}_1-\bar{y})$			
(2) $b_y (\bar{Y}_2-\bar{y})$	\bar{Z}_{12}	$\bar{Z}_{12}(Adj) = \bar{Z}_{12} - b_x(\bar{X}_2-\bar{x}) - b_y (\bar{Y}_2-\bar{y})$			
(3) $b_y (\bar{Y}_3-\bar{y})$	\bar{Z}_{13}	$\bar{Z}_{13}(Adj) = \bar{Z}_{13} - b_x(\bar{X}_3-\bar{x}) - b_y (\bar{Y}_3-\bar{y})$			

In Table II, $\bar{X}_1, \dots, \bar{Y}_1, \dots$, are the initial style means for the independent variable and \bar{Z}_{11}, \dots the initial style means for the dependent variable. $\bar{Z}_1(\text{Adj})$ is the mean of the dependent variable z_1 adjusted to take account of style differences in the independent variables; so that, for example, $\bar{Z}_{13}(\text{Adj})$ is the mean of the z_1 scores adjusted to take account of inter-style differences in x and y .

7. When an observed F is obtained in the final adjusted analysis (Table I) which is larger than $F_{0.05}$ in Snedecor's table, this indicates that the adjusted style means $\bar{Z}_{11}(\text{Adj})$, $\bar{Z}_{12}(\text{Adj})$ and $\bar{Z}_{13}(\text{Adj})$ differ significantly among themselves. Subsequent analysis of the differences among the style means is carried out using the modified 't' test shown in equation (13) with the appropriate standard error indicated by Goulden (1952, p.157). For example, to test the significance of the difference between $\bar{Z}_{11}(\text{Adj})$ and $\bar{Z}_{12}(\text{Adj})$, the adjusted means of z_1 for styles (1) and (2), 't' is found from equation (13).

$$t = \frac{\bar{Z}_{11}(\text{Adj}) - \bar{Z}_{12}(\text{Adj})}{\sqrt{\text{M.S.}(W) \left[\frac{1}{n_1} + \frac{1 + (\bar{X}_1 - \bar{X}_2)}{n_2 \bar{X}(W)} + \frac{(\bar{Y}_1 - \bar{Y}_2)}{\bar{Y}(W)} \right]}} \quad (13)$$

where $\text{M.S.}(W)$ is the 'Within'-style mean square taken from the analysis of covariance; n_1 and n_2 are the numbers of observations in the respective style groups;

\bar{X}_1 , \bar{X}_2 , \bar{Y}_1 , and \bar{Y}_2 , the style means of the independent variables x and y ; and $X_{(w)}$ and $Y_{(w)}$ are the 'Within' sums of squares of x and y .

When equation (13) gives an observed 't' which is larger than that indicated at ' $t'_{0.05}$ ' for the appropriate number of degrees of freedom ($n_1 + n_2 - 2$) it may be concluded that there is a significant difference between the adjusted style means of z_2 .

APPENDIX VIII

ATTITUDE QUESTIONNAIRE

PRETEST VERSION

ATTITUDES TO PHYSICS

In this questionnaire I would like you to tell me what you think about PHYSICS. It is your own opinion that is important. Your answers will not be shown to anyone connected with the school so please be frank. There are no right or wrong answers. It is not a test.

The questionnaire contains a large number of statements. I want to know whether you agree with them or not. On this page there are some practice statements. Place the booklet slightly over your answer sheet so that the spaces for the answers are exactly opposite the statements. You will see that there is a number 4 in the answer box opposite statement A. The answer "Agree" has been chosen here.

If your answer was "Agree" you would also write a 4.

If you felt more strongly than that you would write 5 for "Strongly Agree".

If you disagreed you would write 2 or 1 for "Disagree" or "Strongly Disagree".

If you did not know how you felt or if you were undecided you would write 3 for "Uncertain".

Now try the practice statements yourself:

A. Mathematics is an interesting subject.	5 Strongly Agree
	4 Agree
	3 Uncertain
	2 Disagree
	1 Strongly Disagree

B. Girls do not need to learn mathematics.	5 Strongly Agree
	4 Agree
	3 Uncertain
	2 Disagree
	1 Strongly Disagree

C. Many people find mathematics difficult.	5 Strongly Agree
	4 Agree
	3 Uncertain
	2 Disagree
	1 Strongly Disagree

D. Mathematics is no use to me at home.	5 Strongly Agree
	4 Agree
	3 Uncertain
	2 Disagree
	1 Strongly Disagree

Please do not write anything on this book, and do not open it until you are told to do so.

Read each statement carefully, decide which answer best describes how you feel about the statement and put the number of the answer in the correct box. Please choose only one answer for each statement. Rub out or cross out clearly any answer you wish to change.

Trust your first impressions and work quickly. Try not to spend too long in thinking about any one answer.

Please give an answer to ALL the statements.

1. "Physicists should criticise each others work."	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
2. "I would enjoy doing scientific work when I leave school."	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
3. "Mathematics is a great help to physics."	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
4. "Physics is no use to anyone who is going to be a physical education teacher".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
5. "Physics helps you to develop hobbies outside school."	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
6. "Physics is very useful in several of my other school subjects."	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
7. "If the teacher and I do the same experiment but get different results, the teacher's result is the right one."	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
8. "Only people who are going to do scientific work should have to learn physics."	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
9. "I am not interested in physics."	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
10. "The T.V. Programme "Tomorrow's World" is boring."	5 Strongly Agrees 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree

11. "Biologists studying plants and animals do not need to know anything about electricity".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
12. "Space research is no use to ordinary people".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
13. "If a famous physicist and an unknown physicist disagree we accept the opinion of the famous physicist".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
14. "I enjoy physics".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
15. "Science clubs don't interest me".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
16. "Geography provides examples of things we learn about in physics."	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
17. "Physics needs the understanding and support of ordinary people".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
18. "Physics teachers know the scientific truths".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
19. "I would not like to be a physicist".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
20. "There should be more programmes on T.V. about physics".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree

- | | |
|---|---|
| 21. "If you were interested in studying animals' eyes you would need to know some physics". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 22. "Physics does not affect my daily life at home." | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 23. "A good scientific theory does not supply the final answer to scientific questions". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 24. "Physicists are boring people". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 25. "Astronomy is such an interesting hobby that if I could afford it I would buy an astronomical telescope". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 26. "Physics does not help someone to learn geography". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 27. "Physics should be left to those who are scientists or are going to be scientists". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 28. "Experiments which give answers that disagree with what the teacher expects are useful". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 29. "I wish we had more physics in school". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 30. "Newspapers seldom use physics in discussing news items". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |

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- | | |
|---|---|
| 31. "Physics would be very difficult if we had no mathematics". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
|---|---|
-
- | | |
|---|---|
| 32. "New discoveries in physics are important to everyone". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
|---|---|
-
- | | |
|---|---|
| 33. "If a good physicist says that a theory is true all other physicists will believe him". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
|---|---|
-
- | | |
|---------------------------------|---|
| 34. "Physics is boring for me". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
|---------------------------------|---|
-
- | | |
|---|---|
| 35. "I like tinkering with things like old clocks and radios at home in my spare time". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
|---|---|
-
- | | |
|--|---|
| 36. "Physics does not help you to learn anything about music". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
|--|---|
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|--|---|
| 37. "I make use of physics every day". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 38. "Theories in physics supply the true answer to physics questions". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 39. "I hate physics". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 40. "The school library should have a lot more books about physics". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 41. "Physics does not affect me". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 42. "Physics can help man to live more comfortably". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 43. "Physics teaches us not to believe everything we are told". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 44. "Physicists are very interesting people". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 45. "I like listening to radio programmes which are concerned with physics". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 46. "Chemistry is of little help to physics". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 47. "Everyone in the modern world needs to learn physics". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 48. "A useful theory in physics may not be entirely correct". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 49. "Physics is one of my favourite subjects". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 50. "Pupils who enter for scientific competitions like 'Science Fair' are wasting their time". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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APPENDIX IX

ATTITUDE QUESTIONNAIRE

FINAL VERSION

ATTITUDES TO PHYSICS

In this questionnaire I would like you to tell me what you think about PHYSICS. It is your own opinion that is important. Your answers will not be shown to anyone connected with the school so please be frank. There are no right or wrong answers. It is not a test.

The questionnaire contains a large number of statements. I want to know whether you agree with them or not. On this page there are some practice statements. Place the booklet slightly over your answer sheet so that the spaces for the answers are exactly opposite the statements. You will see that there is a number 4 in the answer box opposite statement A. The answer "Agree" has been chosen here.

If your answer was "Agree" you would also write a 4.

If you felt more strongly than that you would write 5 for "Strongly Agree".

If you disagreed you would write 2 or 1 for "Disagree" or "Strongly Disagree".

If you did not know how you felt or if you were undecided you would write 3 for "Uncertain".

Now try the practice statements yourself:

A. Mathematics is an interesting subject.	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
B. Girls do not need to learn mathematics.	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
C. Many people find mathematics difficult.	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
D. Mathematics is no use to me at home.	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree

Please do not write anything on this book, and do not open it until you are told to do so.

Read each statement carefully, decide which answer best describes how you feel about the statement and put the number of the answer in the correct box. Please choose only one answer for each statement. Rub out or cross out clearly any answer you wish to change.

Trust your first impressions and work quickly. Try not to spend too long in thinking about any one answer.

Please give an answer to ALL the statements.

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|--|---|
| 1. "Physicists should criticise each others work". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 2. "I would enjoy doing scientific work when I leave school". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 3. "Mathematics is a great help to physics". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 4. "I am not interested in physics". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 5. "Physics helps you to develop hobbies outside school". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 6. "If the teacher and I do the same experiment but get different results, the teacher's result is the right one." | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 7. "Physics is very useful in several of my other school subjects". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 8. "The T.V. programme "Tomorrow's World" is boring". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 9. "Only people who are going to do scientific work should have to learn physics". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 10. "I enjoy physics". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |

11. "Biologists studying plants and animals do not need to know anything about electricity".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
12. "If a famous physicist and an unknown physicist disagree we accept the opinion of the famous physicist".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
13. "Space research is no use to ordinary people".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
14. "Science clubs don't interest me".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
15. "Physics teachers know the scientific truths".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
16. "I would not like to be a physicist".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
17. "There should be more programmes on T.V. about physics".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
18. "A good scientific theory does not supply the final answer to scientific questions".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
19. "Physics does not help someone to learn geography".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree
20. "Physicists are boring people".	5 Strongly Agree 4 Agree 3 Uncertain 2 Disagree 1 Strongly Disagree

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| 21. "Physics should be left to those who who are scientists or are going to be scientists". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 22. "Experiments which give answers that disagree with what the teacher expects are useful". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 23. "I wish we had more physics in school". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 24. "New discoveries in physics are important to everyone". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 25. "Physics is boring for me". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 26. "If a good physicist says that a theory is true all other physicists will believe him". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 27. "I like tinkering with things like old clocks and radios at home in my spare time". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 28. "I make use of physics every day". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 29. "I hate physics". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
| 30. "Theories in physics supply the true answer to physics questions". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |

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| 31. "The school library should have a lot more books about physics". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 32. "Physicists are very interesting people". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 33. "Physics teaches us not to believe everything we are told". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 34. "I like listening to radio programmes which are concerned with physics". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 35. "Chemistry is of little help to physics". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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| 36. "Physics is one of my favourite subjects". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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|---|---|
| 37. "A useful theory in physics may not be entirely correct". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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|--|---|
| 38. "Pupils who enter for scientific competitions like 'Science Fair' are wasting their time". | 5 Strongly Agree
4 Agree
3 Uncertain
2 Disagree
1 Strongly Disagree |
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